

487 483
MERRIMACK RIVER BASIN
NASHUA, NEW HAMPSHIRE

MINE FALLS DAM

NH 00116

NHWRB 165.01

PHASE I INSPECTION REPORT
NATIONAL DAM INSPECTION PROGRAM

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DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS. 02154

MARCH 1979

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NH 00116	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Mine Falls Dam NATIONAL PROGRAM FOR INSPECTION OF NON-FEDERAL DAMS		5. TYPE OF REPORT & PERIOD COVERED INSPECTION REPORT
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) U.S. ARMY CORPS OF ENGINEERS NEW ENGLAND DIVISION		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS DEPT. OF THE ARMY, CORPS OF ENGINEERS NEW ENGLAND DIVISION, NEDED 424 TRAPELO ROAD, WALTHAM, MA: 02254		12. REPORT DATE March 1979
		13. NUMBER OF PAGES 63
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) APPROVAL FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES Cover program reads: Phase I Inspection Report, National Dam Inspection Program; however, the official title of the program is: National Program for Inspection of Non-Federal Dams; use cover date for date of report.		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) DAMS, INSPECTION, DAM SAFETY, Merrimack River Basin Nashua, New Hampshire Nashua River		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The dam is a stone masonry gravity dam with a total length of about 325 ft. It is small in size with a low hazard potential. The dam is in fair condition at the present time. In light of the dam's fair condition technical inspections should be made every year.		



DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM, MASSACHUSETTS 02154

REPLY TO
ATTENTION OF:
NEDED

JUN 29 1979

Honorable Hugh J. Gallen
Governor of the State of New Hampshire
State House
Concord, New Hampshire 03301

Dear Governor Gallen:

I am forwarding to you a copy of the Mine Falls Dam Phase I Inspection Report, which was prepared under the National Program for Inspection of Non-Federal Dams. This report is presented for your use and is based upon a visual inspection, a review of the past performance and a brief hydrological study of the dam. A brief assessment is included at the beginning of the report. I have approved the report and support the findings and recommendations described in Section 7 and ask that you keep me informed of the actions taken to implement them. This follow-up action is a vitally important part of this program.

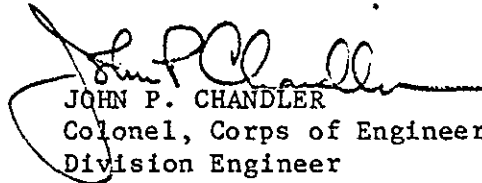
A copy of this report has been forwarded to the Water Resources Board, the cooperating agency for the State of New Hampshire. In addition, a copy of the report has also been furnished the owner, Mr. Maurice L. Arel, Mayor, City of Nashua, Nashua, New Hampshire 03060.

Copies of this report will be made available to the public, upon request, by this office under the Freedom of Information Act. In the case of this report the release date will be thirty days from the date of this letter.

I wish to take this opportunity to thank you and the Water Resources Board for your cooperation in carrying out this program.

Sincerely yours,

Incl
As stated


JOHN P. CHANDLER
Colonel, Corps of Engineers
Division Engineer

MINE FALLS DAM
NH 00116

MERRIMACK RIVER BASIN
NASHUA, NEW HAMPSHIRE

PHASE I INSPECTION REPORT
NATIONAL DAM INSPECTION PROGRAM

NATIONAL DAM INSPECTION PROGRAM

PHASE I REPORT

Identification No.: NH 00116
NHWRB No.: 165.01
Name of Dam: MINE FALLS DAM
City: Nashua
County and State: Hillsborough County, New Hampshire
River: Nashua River
Date of Inspection: November 8, 1978

BRIEF ASSESSMENT

Mine Falls Dam is a stone masonry gravity dam with a total length of about 325 feet. The dam includes a spillway with a length of 145 feet, a headworks structure with an outlet canal, a training wall separating the gate house and the right end of the spillway, a training wall on the right upstream bank, an end wall on the left bank, and a downstream canal training wall. The headworks structure has five wooden gates approximately 6 feet wide by 9.5 feet high which discharge into a canal to the right of the spillway. Four of these gates are inoperable with three of the gates being permanently sealed with concrete. The fifth gate is left open at all times.

The present dam was built in 1928 to replace a former dam which was washed out during the 1927 flood. The dam was originally owned by the Nashua Manufacturing Company and was used to supply water for power at downstream mills. At a later date Textron, Inc. of Nashua, N.H. acquired the dam. The dam is presently owned by the City of Nashua, who obtained it from Nashua Foundation Company in 1969, and is operated through the Nashua Department of Parks and Recreation.

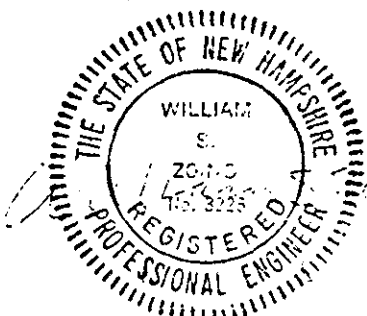
The dam, which lies on the Nashua River, is used for recreational purposes. The total drainage area for the dam is 524 square miles with 117 square miles of drainage being diverted to the Wachusett Reservoir. The dam's maximum impoundment of 650 acre-feet and height of 24 feet place it in the SMALL size category. In the event of a failure, little damage would be expected resulting in a LOW hazard potential classification.

Based on the size and hazard classifications, and in accordance with the Corps of Engineers guidelines, the Test Flood (TF) would be between the 50 and 100-year floods. Since the hazard potential classification is on the high side of the LOW category, the test flow to the dam was taken as the 100-year flood.

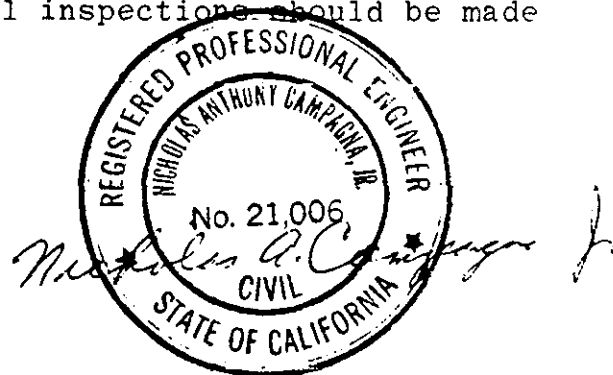
The 100-year flood yields an inflow of 20,180 cfs to the dam. Because of the small storage available at the dam, little attenuation of flow would occur through the pond. The spillway capacity is 14,900 cfs which is 73% of the TP. If the one head gate were open, the peak flow would be about 10.3 feet above the spillway crest or about 1.2 feet above the top of the stone retaining wall, which is considered the top of the dam for the purposes of this report.

Mine Falls Dam is in FAIR condition at the present time. It is recommended that engineering evaluations be made into the condition of the five sluice gates, the extent of masonry unravelling between the Gate No. 5 tunnel outlet and the left canal wall, the source of seepage emanating through the rock outcrop immediately downstream of the right side of the spillway, and the downstream flow conditions in the canal in the event that the sluice gates failed. The findings should be implemented by the owner. Recommended remedial measures include repair of the base of the headwall adjacent to the canal wall, the reconstruction of the left canal wall on a competent foundation, and repair of the cracks in the left end wall.

The recommendations outlined above should be implemented within one year of receipt of this report by the owner. In light of the dam's FAIR condition, technical inspections should be made every year.



William S. Zoino
New Hampshire Registration 3226



Nicholas A. Campagna, Jr.
California Registration 21006

This Phase I Inspection Report on Mine Falls Dam has been reviewed by the undersigned Review Board members. In our opinion, the reported findings, conclusions, and recommendations are consistent with the Recommended Guidelines for Safety Inspection of Dams, and with good engineering judgment and practice, and is hereby submitted for approval.

Joseph A. McElroy

JOSEPH A. MCELROY, MEMBER
Foundation & Materials Branch
Engineering Division

Carney M. Terzian

CARNEY M. TERZIAN, MEMBER
Design Branch
Engineering Division

Joseph W. Finegan, Jr.

JOSEPH W. FINEGAN, JR., CHAIRMAN
Chief, Reservoir Control Center
Water Control Branch
Engineering Division

APPROVAL RECOMMENDED:

Joe B. Fryar

JOE B. FRYAR
Chief, Engineering Division

PREFACE

This report is prepared under guidance contained in the Recommended Guidelines for Safety Inspection of Dams for Phase I Investigations. Copies of these guidelines may be obtained from the Office of Chief of Engineers, Washington, D.C. 20314. The purpose of a Phase I Investigation is to identify expeditiously those dams which may pose hazards to human life or property. The assessment of the general condition of the dam is based upon available data and visual inspections. Detailed investigation and analyses involving topographic mapping, subsurface investigations, testing, and detailed computational evaluations are beyond the scope of a Phase I investigation; however, the investigation is intended to identify any need for such studies.

In reviewing this report, it should be realized that the reported condition of the dam is based on observations of field conditions at the time of inspection along with data available to the inspection team. In cases where the reservoir was lowered or drained prior to inspection, such action, while improving the stability and safety of the dam, removes the normal load on the structure and may obscure certain conditions which might otherwise be detectable if inspected under the normal operating environment of the structure.

It is important to note that the condition of a dam depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through continued care and inspection can unsafe conditions be detected.

Phase I inspections are not intended to provide detailed hydrologic and hydraulic analyses. In accordance with the established Guidelines, the Test Flood is based on the estimated "Probable Maximum Flood" for the region (greatest reasonably possible storm runoff), or fractions thereof. Because of the magnitude and rarity of such a storm event, a finding that a spillway will not pass the Test Flood should not be interpreted as necessarily posing a highly inadequate condition. The Test Flood provides a measure of relative spillway capacity and serves as an aid in determining the need for more detailed hydrologic and hydraulic studies, considering the size of the dam, its general condition and the downstream damage potential.

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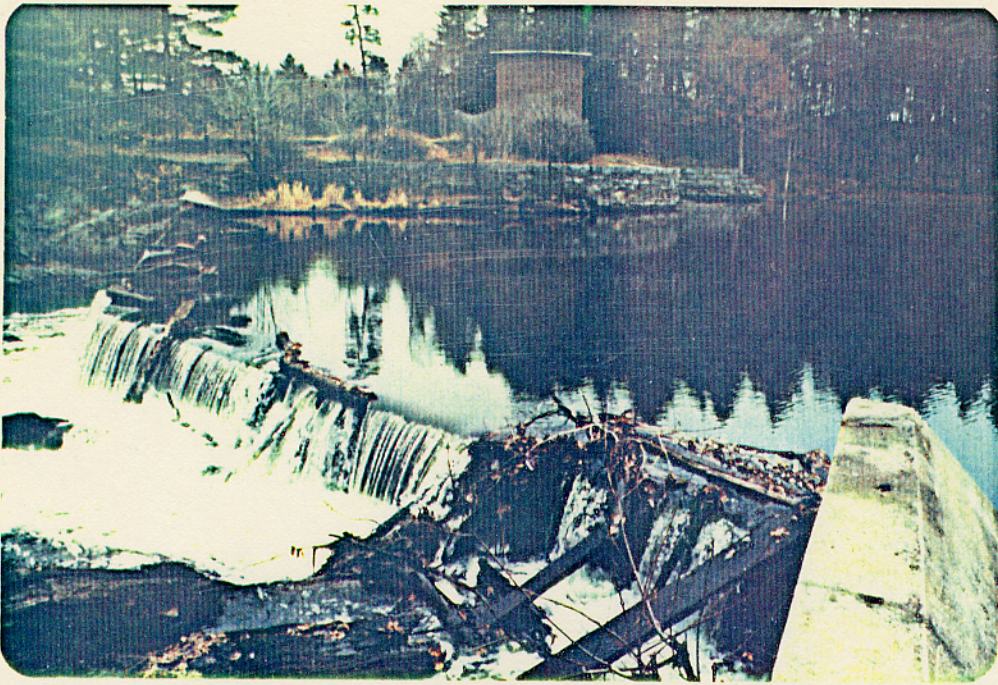
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Overview from left abutment



Overview of spillway from right end
of spillway

PHASE I INSPECTION REPORT

MINE FALLS DAM

SECTION 1

PROJECT INFORMATION

1.1 General

(a) Authority

Public Law 92-367, August 8, 1972, authorized the Secretary of the Army, through the Corps of Engineers, to initiate a national program of dam inspection throughout the United States. The New England Division of the Corps of Engineers has been assigned the responsibility of supervising the inspection of dams within the New England Region. Goldberg, Zoino, Dunnicliff & Associates, Inc. (GZD) has been retained by the New England Division to inspect and report on selected dams in the State of New Hampshire. Authorization and notice to proceed was issued to GZD under a letter of November 28, 1978 from Colonel Max B. Scheider, Corps of Engineers. Contract No. DACW 33-79-C-0013 has been assigned by the Corps of Engineers for this work.

(b) Purpose

- (1) Perform technical inspection and evaluation of non-federal dams to identify conditions which threaten the public safety and thus permit correction in a timely manner by non-federal interests.
- (2) Encourage and prepare the states to initiate quickly effective dam safety programs for non-federal dams.
- (3) Update, verify, and complete the National Inventory of Dams.

(c) Scope

The program provides for the inspection of non-federal dams in the high hazard potential category based upon location of the dams and those dams in the significant hazard potential category believed to represent an immediate danger based on condition of the dam.

1.2 Description of Project

(a) Location

Mine Falls Dam lies on the Nashua River approximately 2 miles west southwest of the center of Nashua, N.H. The dam is approximately 4.5 miles upstream from the confluence of the Merrimack and Nashua Rivers. The dam is accessible by dirt roads or foot from Route 111 (West Hollis Street) in Nashua. The portion of the USGS Pepperell, MA-NH quadrangle presented previously shows this locus. Figure 1 of Appendix B presents a detail of the site developed from the inspection visit, the quadrangle map, and site plans in the files of the New Hampshire Water Resources Board.

(b) Description of Dam and Appurtenances

The dam consists of the following basic components:

- 1) A stone masonry spillway
- 2) A headworks structure (gate house) with an outlet canal
- 3) A backward "J" shaped training wall separating the headworks and the right end of the spillway
- 4) An end wall on the left bank
- 5) A downstream canal training wall (left side)
- 6) An intermediate wall between the left canal training wall and the right training wall upstream of the spillway
- 7) A stone wall extending from the left canal wall across the canal and into the right bank
- 8) A granite block wall extending from the right side of the gate house into the right bank
- 9) A flume, which acts as a waste outlet and is located adjacent to the right training wall of the spillway

The figure located on page B-3 of Appendix B shows a plan of these various components.

The overall length of the dam is about 325 feet of which about 145 feet is spillway. The many different levels of concrete structures at the dam make the choice of one elevation as the top of the dam a difficult one. The left end of the dam is 3.5 feet above the spillway crest. In previous studies, however, the top of the dam was taken as the top of the backward "J" shaped training wall separating the headworks and the right spillway end wall. The top elevation of this wall is 9.1 feet above the spillway crest. The ground elevation between the spillway training wall and the right end of the dam (where it joins the natural hillside) is about 13.5 feet above the spillway crest elevation. Field observations indicate that all structures are founded on rock.

(1) Left End Wall (Item A of Fig. B-3)

This concrete wall, which is approximately 45 feet long, angles back to the left bank. The left bank climbs very steeply from the end of this wall. The top width of the wall is approximately 1.5 feet wide and has a back batter of 6 horizontal to 12 vertical.

(2) Spillway (Item B of Fig. B-3)

The spillway is a stone masonry structure with a "V" shape located approximately 48 feet from the left end wall, and the apex angle is approximately 150° . The total length of the spillway is about 145 feet.

(3) Right End Wall of Spillway (Item C of Fig. B-3)

This wall consists of cemented stone masonry with a concrete cap and is about 22 feet long. A 2.5 foot high by 2.0 foot wide flume penetrates through the stone masonry. A dry stone masonry training wall extends approximately 30 feet downstream from the end of the spillway wall.

(4) Right Backward "J" Training Wall (Item D of Fig. B-3)

This structure starts at the spillway end wall, continues upstream for a total of about 90 feet in a "J" shape and then loops back into the gate house structure with a portion of the wall acting as a training wall leading to the gate house. The total length of the wall is about 125 feet.

(5) Flume (Waste Outlet and Fish Channel)
(Item E of Fig. B-3)

This structure is located immediately adjacent to the right training wall. The flume channel is approximately 30 feet long, 2.5 feet wide and 3.5 feet deep. The structure is constructed out of dry granite blocks and is about 12 feet wide at its upstream end and 20 feet wide at its downstream end.

(6) Headworks Structure (Gate House) (Item F of Fig. B-3)

This structure is 20 feet wide and 55 feet long and has 14 inch brick bearing walls supported on a cemented quarried granite foundation. The flat roof is timber framed. The service floor of the structure is 11.7 feet above the spillway crest, and the pit elevation is 8.9 feet lower. This structure houses five timber sluice gates which outlet into the canal. These sluice gates are approximately 7 feet wide and 17 feet high. The openings are 6 feet wide and 9.5 feet high.

(7) Right Upstream Training Wall (Item G of Fig. B-3)

This structure, consisting of cemented squared stone masonry, is 4 feet wide on its top surface and approximately 70 feet long. This wall is located normal to the right side of the headworks structure. The upstream end of this wall is approximately 8 feet above crest level. The wall ends next to the headworks structure. At this point it is approximately 12 feet above crest level.

(8) Cut-Off Wall (Item H of Fig. B-3)

The structure, consisting of cemented squared stone masonry, is approximately 3.5 feet wide and approximately 65 feet long. The wall starts midway along the right side of the headworks foundation and extends normally from this location to bedrock on the right bank.

(9) Head Wall (Item I of Fig. B-3)

This wall starts at its intersection with the left canal training wall, extends across the canal into the right bank for a distance of about 120 feet, and then turns at a 90° angle downstream for about another 18 feet.

(10) Canal Training Wall (Item J of Fig. B-3)

This structure is constructed with cemented rubble stone masonry and is founded on exposed bedrock. The wall is approximately 75 feet long. Approximately 60 feet downstream of its terminus with the downstream head wall, the wall returns for a distance of approximately 16 feet into the left bank.

(11) Intermediate Wall (Item K of Fig. B-3)

This wall, located between the canal wall and the right spillway end wall, has an "L" shape and consists of dry stone masonry. The wall starts at the left end of the headworks structure and ends approximately midway between the canal training wall return and the right training wall extension below the spillway.

(c) Size Classification

The dam's maximum impoundment of 600 acre-feet and maximum height of 24 feet are below the 1,000 acre-foot and 40 foot limits for the SMALL size category as defined in the "Recommended Guidelines."

(d) Hazard Potential Classification

The hazard potential classification is considered to fall in the LOW category. Analyses revealed that a dam failure would not affect downstream structures unless the stream stage is very high already. This is discussed in detail in Section 5.

(e) Ownership

The dam is owned by the City of Nashua, N.H.

(f) Operator

The dam is operated by the City of Nashua's Department of Parks and Recreation. Mr. Noel Trottier is director of the Department, and Mr. Ed Schroeder is the Superintendent of Parks. These men can be reached by telephone at 603-880-3367 or 603-880-3346.

(g) Purpose of Dam

The original purpose of the dam was to provide power to mills located downstream from the dam. The dam presently serves recreational purposes only.

(h) Design and Construction History

The dam was built in 1928 after a flood in 1927 washed out the previous dam at the site. The original owner of the dam was the Nashua Manufacturing Company and was used to supply power to downstream dams. At a later date, the dam was acquired by Textron, Inc. Nashua Foundation Company purchased the dam in 1948 or 1949 and owned the dam until 1969 when the City of Nashua obtained the dam.

(i) Normal Operational Procedures

In general, no operation of the dam is performed. The dam is inspected at frequent, although irregular, intervals by representatives of the Nashua Department of Parks and Recreation. The lone operating gate is left open at all times unless repair or maintenance work to the downstream canal is necessary. When such work is performed, the gate is closed, and the stop logs at the emergency spillways downstream are pulled to lower the water level in the canal. When high water levels from flooding are expected, the stop logs in the spillways are also pulled to prevent downstream flooding of the canal.

1.3 Pertinent Data

(a) Drainage Area

The total drainage area for the dam is 524 square miles. Of this total 117 square miles of drainage area is diverted to the Wachusett Reservoir for use by the Metropolitan District Commission to supply the metropolitan Boston area with water. The net drainage area for the dam is therefore 407 square miles.

(b) Discharge at Damsite

(1) Outlet Works

There is only one operating outlet structure

at the dam. This outlet is a 6 foot wide by 9.5 foot high gate located in the gate house which allows water to flow into the canal and Mill Pond. This outlet has an invert elevation of 141 and is left permanently open.

(2) Maximum Flood at Damsite

Records of gauge readings taken at the dam during the first three months of 1936 were available and likely represent the largest flood experienced at the dam. The highest water level was 10.5 feet above the spillway crest and was measured on March 20, 1936. This calculates to be a flow of 20,700 cfs, based on the stage-discharge calculations for the dam.

(3) Spillway Capacity at Maximum Pool Elevation

14,900 cfs at elevation 164.0

(4) Gated Capacity at Normal Pool Elevation

850 cfs at elevation 154.9

(5) Gated Capacity at Maximum Pool Elevation

1280 cfs at elevation 164.0

(6) Total Discharge Capacity at Maximum Pool Elevation

16,200 cfs at elevation 164.0

(c) Elevation (feet MSL)

(1) Top of dam: 164.0

(2) Maximum pool: 164.0

(3) Spillway crest: 154.9

(4) Recreational pool: 154.9

(5) Gate invert: 141.0

(6) Streambed: 140.0

(7) Maximum tailwater: Unknown

(d) Reservoir

- (1) Length - maximum pool: 12,000 feet \pm
recreational pool: 10,000 feet \pm
- (2) Storage - maximum pool: 650 acres \pm
recreational pool: 500 acres \pm
- (3) Surface - maximum pool: 60 acres \pm
recreational pool: 55 acres \pm

(e) Dam

- (1) Type: stone masonry gravity dam
- (2) Length: 325 feet
- (3) Height: 24 feet
- (4) Top width: 4 feet at spillway

(f) Spillway

- (1) Type: stone masonry gravity with vertical drop
- (2) Length of weir: 145 feet
- (3) Crest elevation: 154.9
- (4) U/S channel: broad approach from pond
- (5) D/S channel: width of river

(g) Regulating Outlets

See section 1.3 (b) (1) of this report.

SECTION 2 - ENGINEERING DATA

2.1 Design Records

The design of this dam is quite simple and incorporates no unusual features. None of the original design drawings or calculations are available for the dam.

2.2 Construction Records

No plans or records of construction of value are available for review.

2.3 Operational Records

The owner operates the dam in a manner consistent with its purpose and engineering features.

2.4 Evaluation of Data

(a) Availability

The absence of design drawings and calculations is a significant shortcoming. An overall unsatisfactory assessment for availability is therefore warranted.

(b) Adequacy

The lack of in-depth engineering data does not permit a definitive review. Therefore, the adequacy of the dam cannot be assessed from the standpoint of reviewing design and construction data. This assessment of the dam is thus based primarily on the visual inspection, past performances and sound engineering judgment.

(c) Validity

Since the observations of the inspection team generally confirm the information contained in the available drawings, a satisfactory evaluation for validity is indicated.

SECTION 3 - VISUAL OBSERVATIONS

3.1 Findings

(a) General

Mine Falls Dam is in FAIR condition at the present time.

(b) Dam

(1) Left End Wall (Item A of Fig. B-3)

The upstream end of this structure adjacent to the spillway is badly eroded. This is attributed to ice damage and moisture intrusion which has been subjected to alternating freeze and thaw cycles. Visual observations of the upstream end revealed that the original concrete structure has been capped and faced on both sides with concrete. The capping raised the wall an additional two feet. A series of horizontal cracks with considerable efflorescence are located over the front face of the wall from the interface with the spillway for an approximate distance of 20 feet. The entire length of this wall is highly effloresced over approximately 80 percent of its surface area below the original top of the wall. The upstream face of the wall has a continuous horizontal crack at the former top elevation of the structure. This is up to 2 inches in width and is attributed to stress concentration created by the capping procedure.

(2) Spillway (Item B of Fig. B-3)

The spillway structure is in good condition without any evidence of displaced stones, bulges, or other signs of distress. The joints are almost void of mortar and seepage was observed at isolated locations.

(3) Right End Wall of Spillway (Item C of Fig. B-3)

This structure consists of cemented stone masonry with a concrete cap founded at the spillway crest elevation. It was observed that the concrete cap on this structure is in good condition with the exception of honeycombing over 10% of its surface area.

There is no evidence of cracks or spalls on this portion of the structure, however, there are isolated locations of minor efflorescence. A close observation of the stone masonry portion of this structure revealed that the quarried stone had been laid up in mortar but at the time of inspection the joint mortar was spalled. The stone masonry portion of this structure does not reveal any evidence of displaced stones, bulges, or other signs of distress. The masonry outlet of the upstream flume has been sealed with random cemented stone masonry. There is no evidence of seepage through the outlet. Vegetation is flourishing in the stone masonry at the flume outlet. It was observed that steady seepage, at extremely low flow rates, is flowing through the masonry joints in this structure. Steady seepage is also flowing through rock fissures adjacent to the right spillway end wall approximately 6 feet below its top surface, and the combined rate of flow is estimated to be approximately 10 to 15 gpm.

Approximately 5 feet downstream of this structure it was observed that a steady flow of water is discharging through an 8-inch cast iron pipe at tailwater elevation. It is estimated that this discharge is at the rate of 3 to 5 cfs. Attempts were made to locate the inlet of this pipe but without any tangible results. Investigations of the rock foundation of the left canal wall did not reveal any evidence of rock removal at or above the canal backwater level which is indicative of some form of drain outlet.

(4) Right Backward "J" Training Wall (Item D of Fig.B-3)

This cemented stone masonry wall is in good condition and does not reveal any evidence of displaced stones, bulges, or other signs of distress. Minor joint erosion was observed at the normal water surface level. This erosion is attributed to ice damage and moisture intrusion which has been subjected to alternating freeze and thaw cycles. Joint efflorescence was observed, but it is minor.

(5) Waste Outlet Flume (Item E of Fig. B-3)

This structure consists of built up dry stone masonry with an integrally constructed flume. This flume extends from a concrete headwall upstream of the spillway crest and terminates at the upstream side of the right spillway end wall. At the present time, this structure has been sealed at its tunnel outlet within the right spillway end wall and does not serve any useful purpose. Investigations did not reveal any evidence of a former sluice gate or other means of water regulation.

(6) Headworks Structure (Item F of Fig. B-3)

In general, this structure is in good condition. At the present time there are two entrances. The left entrance has been welded shut to preclude vandalism; the right entrance is locked with access controlled by the City of Nashua. No evidence of distress was observed on the first floor concrete slab or the timber column, girt, and beam roofing system. This timber framing system currently is supporting live loads consisting of five granite blocks approximately 2 feet wide, 3 feet high, and 8 feet long or a total estimated weight of 19 tons for the five counterweights.

The gate pit floor, which is approximately 9 feet below the main floor, consists of timber decking supported on brick and granite ledgers. This flooring system could not be used in the event the sluice gates were rehabilitated because of the safety hazard for operating personnel. The brick partitions dividing the sluice gate bays are in good condition, however, their stone masonry foundations could not be observed to evaluate structural integrity. Available plans indicate that 2 foot square overflow openings are located within each of the brick sluice bay walls approximately 2.5 feet below the spillway crest elevation. The 1971 modifications to the headworks structure detailed the sealing of gates Nos. 1, 3 and 5 at their upstream face. These modifications did not detail the sealing of the overflow openings and inspection was precluded because they were submerged. In the event that these openings were not sealed, all gates would be subjected to full hydrostatic heads.

In the past the gate operating equipment was electrically operated. Power to this structure has been disconnected. The electric power system consisted of a main drive motor which activated a steel chain belt with a combination of pulley systems which drove a primary shaft. The chain drives have been identified as "Morse Silent Chain" manufactured by Morse Chain Company, Ithica, N.Y. The power drive was transmitted to the individual gate operating systems by means of "on-line" clutches. The electric drive system has been partially dismantled.

Manual operation of the sluice gate mechanisms is with a hand crank operated shaft with a worm gear which drives a bull gear. When electrically operated the hand crank was by-passed. The individual bull gears activated dual ratchet gears, which meshed with rack gears fastened to the gate frames. As previously mentioned, each of the gates are counterbalanced by suspended granite blocks. The counterbalance is accomplished through chains connected to the gates, riding over pulleys, and attached to the granite blocks. Manual operation of an operable gate within this structure would require extensive effort on the part of two individuals.

The five sluice gates are located in an offset position within the structure. For identification purposes gate No. 1 is located at the right end of the structure looking downstream and the additional gates are identified in numerical sequence to the left. Gates 1, 3, and 5 have been sealed with precast concrete panels 8' wide, 10'-9" high and 8" thick. Gates 2 and 4 are technically operable. Observations from the lower service platform have revealed the following conditions of the gates.

Gate No. 1 - The entrance to this gate has been sealed with a precast concrete bulkhead. There is evidence of seepage flowing around this structure. The timber gate frames appear to be in good condition.

Gate No. 2 - This gate is not operable according to the Nashua Department of Parks and Recreation.

Gate No. 3 - The entrance of this gate has been sealed with a precast concrete bulkhead. There is evidence of seepage flowing around this structure. The timber gate frames are completely rotted and are no longer operational.

Gate No. 4 - This gate is operable. At the time of inspection this gate had been raised approximately 4 inches to provide discharge in the outlet canal. The gate frame has been heavily braced with cross framing and horizontal members. The rack gears are well greased. The base of the rack stems are badly rotted at their base connection with the sluice gate itself.

Gate No. 5 - The entrance to this gate has been sealed with a precast concrete bulkhead. There is evidence of seepage flowing around this structure. Both timber vertical stems of this gate have disintegrated. There is audible evidence of seepage through, over, or around this gate. The Parks Department indicated that this gate is open 6 inches and cannot be closed.

During the course of field investigations the materials, fabrication, and the condition of the sluice gates could not be observed because they were submerged.

Observations revealed that no trash racks or provisions for stop logs have been incorporated into the structure.

(7) Right Upstream Training Wall (Item G of Fig. B-3)

This cemented stone masonry wall is in good condition and does not have any displaced stones, bulges, or signs of distress. Minor joint erosion was observed at the normal water surface level which is attributed to ice damage and moisture intrusion which has been subjected to alternating freeze and thaw cycles.

(8) Cut-Off-Wall (Item H of Fig. B-3)

This structure, which is isolated between the headworks structure and the right bank, is completely buried with the exception of its top surface. The top mortared joints are intact, but because the structure is buried, further inspection could not be made.

(9) Head Wall (Item I of Fig. B-3)

Observations of this structure revealed that the portion of this structure immediately opposite of the headworks was constructed in two separate stages. The lower portion of this wall is clearly defined by means of a granite sill which, in all probability, was a former capstone. The top of this sill is approximately at spillway crest elevation. Later the wall was increased in height and extended to the right bank. The original wall consists of cemented squared stone masonry whereas the upper portion of this wall and the extension to the right bank was constructed with irregular patterns of split stone set in mortar. A cemented squared stone masonry parapet wall, approximately 3.5 feet high, was constructed opposite the downstream side of the headworks structure. Portions of the capstone are missing. Visual observations revealed that the mortared joints of the original wall below the capstone are highly effloresced with minor exudation. This is attributed to moisture intrusion through the back side of the wall. Stones have been dislodged at the base of the left end of this structure adjacent to the left canal wall. This erosion, as measured above the water line, is approximately 2 feet high, 12 inches wide, and 2 to 3 feet deep. The extent of erosion below the water level surface could not be determined.

This structure also serves as the outlet for the five sluice gates. The outlet tunnels are made of cemented stone masonry and the exterior faces of these tunnels are supported on granite headers. With the exception of open joints over the intermediate pilasters, these headers are in good condition. Observations of the wall section between the end of the headworks structure and the right bank did not reveal any structural deficiencies. Remnants of a metal rail fence are evident over the length of this wall.

The 5 foot chain link fence over the length of this structure is in poor condition because of vandalism but is in serviceable condition.

(10) Canal Training Wall (Item J of Fig. B-3)

The canal training wall, which is made of cemented random stone masonry, is in fair condition. The return of this wall is in good condition. Visual observations revealed that the bedrock foundation of this structure has decomposed and eroded. In some instances this foundation erosion extends up to two feet under the stone masonry. Trees and saplings up to 6 inches in diameter are growing through the rock fissures at the wall base.

(11) Intermediate Wall (Item K of Fig. B-3)

This intermediate wall consists of a low height "terrace" type wall designed to raise the elevation of the dam's earth embankment adjacent to the spillway crest and right spillway end wall. At various locations, the capstones of this wall have been dislodged by acts of vandalism. With the exception of dislodged capstones, the exposed vertical face of this structure, up to 4 feet in height, does not exhibit any bulges or other signs of distress.

3.2 Evaluation

Mine Falls Dam is in FAIR condition. Some concrete deterioration has occurred, and some seepage through joints was observed. Most of the major dam components were accessible for examination, although it was not possible to examine the complete condition of the gates and the precast concrete seals.

SECTION 4 - OPERATIONAL PROCEDURES

4.1 Procedures

There is no formal operating procedure for the dam. The dam is inspected by personnel of the Department of Parks and Recreation at irregular periods. The only operating procedure occurs when repair work at the canal is required. In that case, the only operating gate is closed, and the stop logs at the emergency spillways in the pond are removed to drain the pond. The stop logs are also removed during periods of expected flooding to prevent flooding in the canal.

4.2 Maintenance of the Dam

No formal maintenance program exists for the dam. The dam is inspected by representatives of the Department of Parks and Recreation, however, no maintenance program exists for the dam.

4.3 Maintenance of Operating Facilities

The only operating facilities are the two emergency spillways in the canal which have stop logs and the operating sluice gate at the gate house. The gate is in good operating condition.

4.4 Description of Any Warning System in Effect

There is no formal warning system in effect for this dam.

4.5 Evaluation

The maintenance and operating procedures for the dam are adequate for the normal operation of the dam. Some remedial measures are required at the dam to allow its continued long-term use.

SECTION 5 - HYDRAULICS/HYDROLOGY

5.1 Evaluation of Features

(a) General

Mine Falls Dam is a stone masonry structure on the Nashua River one mile upstream of downstream Nashua, New Hampshire. It is a run-of-the-river structure which originally diverted flows into the Nashua Canal for industrial uses. The canal area is now a recreational park.

The spillway is a stone masonry broad crested weir about 145 feet in length. There is also a head-works structure to the right of the spillway. This controls flows into the Nashua Canal. There is only one operational gate in this structure. It has a 6 foot wide by 9.5 foot high outlet opening.

(b) Available Data

Data sources available for Mine Falls Dam include prior inventory and inspection reports. The New Hampshire Water Control Commission's "Data on Dams in New Hampshire" (April 10, 1939); the Public Service Commission of New Hampshire's "Dam Record" (August 31, 1936); and the New Hampshire Water Resources Board's "Inventory of Dams and Water Power Developments" (October 31, 1936) provide much of the basic data for the dam. Inspection reports from July 8, 1930, June 18, 1940, June 22, 1951, and October 8, 1975 are also available. Anderson-Nichols and Company, Inc. provided copies of data, computations, and drawings performed for a Flood Insurance Study which included the Nashua River and the Mine Falls Dam. These included cross-section data and 10, 50, 100, and 500-year peak discharges at various points on the Nashua River as well as Flood Boundary Work Maps for the reach downstream of the dam.

Also available are drawings, calculations and reports concerning projects related to the Mine Falls Dam. These include a "Report on Hydraulics and Control Facilities of the Nashua River Canal" and a site plan and gatehouse drawings for the Mine Falls Gate House Project prepared in 1971 by Hamilton Engineering Associates, Inc.; and a Site Development Plan for Mine Falls Park and a design analysis of an emergency spillway from Mill Pond (part of the Nashua River Canal) prepared in 1974-1975 by Smith and Hamilton, Inc.

(c) Experience Data

The only available data on flood levels at the Mine Falls Dam are a set of gauge readings taken during the first three months of 1936. The highest level reported is approximately 10.5 feet above the spillway crest on March 20, 1936. This equates to a flow of approximately 20,700 cfs, based on the stage-discharge relation at the dam (see Appendix D).

(d) Visual Observations

The upstream channel leading to the dam and spillway is a broad approach from the pond with no obstruction.

The downstream channel can be divided into two separate conditions. The diversion channel through the gate house leads to a canal which winds about 2 miles to a mill downstream from the dam. Two emergency spillway structures are located off the canal which divert flow from the canal back to the main river channel.

About 100 feet downstream from the dam the Nashua River passes a very narrow, constricted channel section and enters a reach of rapids which is about 500 in feet in length with a narrow, steeply sloping, rocky channel. This is followed by a portion of braided stream before the river returns to a single channel of milder slope at a point about 1500 feet downstream from the dam.

The flood plain is relatively restricted, and there are no structures threatened by flooding until approximately one mile downstream of the dam where there is development in the flood plain on the left bank. After this point, the flood plain opens out somewhat, but no structures appear to be endangered by flooding for another two miles downstream.

(e) Test Flood Analysis

The hydrologic conditions of interest in this Phase Investigation are those required to assess the dam's overtopping potential and its ability to safely allow an appropriately large flood to pass. This requires using the discharge and storage characteristics of the structure to evaluate the impact of an appropriately-sized Test Flood. None of the original hydraulic and hydrologic design records are available for use in this study.

Guidelines for establishing a recommended Test Flood based on the size and hazard classifications of a dam are specified in the "Recommended Guidelines" of the Corps of Engineers. The impoundment of less than 1000 acre-feet and height of less than 40 feet classify this dam as a SMALL structure.

The hazard potential for the Mine Falls Dam is considered to fall within the LOW category. This is based mainly on the fact that the dam failure outflow will not affect structures downstream unless the stream stage is very high already. At such high stages, the dam failure will add less than a 10 percent increment to the stream discharge.

As shown in Table 3 of the Corps of Engineers' "Recommended Guidelines," the appropriate Test Flood for a dam classified as SMALL in size with LOW hazard potential would be between the 50-year flood and the 100-year flood. Where a range of values is indicated for the Test Flood, the magnitude should be related to the hazard potential. Since the hazard is on the high side of the LOW category, the Test Flood flow selected for Mine Falls Dam is the 100-year flood.

Previous ANCO FIS study results provided estimated values for the 10, 50, 100 and 500-year discharges at Mine Falls Dam. The computed 100-year flow rate of 20,180 cfs will be adopted as the applicable Test Flood. Storage routing through the reservoir was not considered because the surcharge storage volume available is too small to have a significant effect, when compared to the large runoff volumes that a watershed of this size will generate. For this reason, a stage-storage relation has not been calculated for the Mine Falls Dam.

The stage-discharge curve is developed by defining discharge as the sum of flow over the spillway, flow over the dam crest, and flow over the side slopes and side walls at the ends of the dam as well as flow through one head gate into the Nashua Canal. The calculations determining these curves are documented in Appendix D.

The peak test discharge of 20,180 cfs would result in a maximum stage of 10.3 feet above the spillway crest, or 1.2 feet over the top of the stone retaining wall at the right end of the spillway which retains an earth slope between the spillway and the gate house.

The results of the hydrologic and hydraulic calculations indicate that flood levels 1.2 feet above the retaining wall at the right end of the spillway would be experienced for the recommended Test Flood. It should be noted, however, that an even higher level, about 1.4 feet above the retaining wall, was reported for March 20, 1936 and no major damage to the dam was reported. It is uncertain that the dam is in an equivalent state of repair at this time.

Should a failure occur with a pool elevation 3 feet above the spillway crest, the resulting flood wave would be contained within the main stream channel causing little or no damage downstream. A dam failure with the pool 9.1 feet above the spillway crest would increase the downstream discharge by less than 10 percent, and flood depths at a developed area in the flood plain one mile downstream would be increased by less than one foot as a consequence. This does not represent an additional significant downstream hazard.

(f) Dam Failure Analysis

The peak outflow at Mine Falls Dam that would result from dam failure is estimated using the procedure suggested in the Corps of Engineers New England Division's April 1978 "Rule of Thumb Guidelines for Estimating Downstream Dam Failure Hydrograph." Two different preconditions to failure are considered because there are two possible definitions for the top of the dam.

For the first case, failure is assumed to occur as soon as the concrete walls flanking the (main) spillway are overtopped at an elevation of 157.0 feet. Based on the rating curve, the spillway discharge would be 2340 cfs for this elevation. This is 3.0 feet above the spillway crest and 13.9 feet above the tailwater level at this discharge. Assuming a 42 foot gap is opened in the dam, the peak failure outflow through this gap and over the rest of the spillway would be 6000 cfs.

In the second case, failure is assumed to occur when the upstream pool exceeds the top of the stone retaining wall at the right end of the spillway at elevation 164.0. Based on the rating curve, the spillway discharge for this elevation would be 14,960 cfs.

This is 9.1 feet above the spillway and 6.5 feet above the tailwater at this discharge. The peak failure outflow through the 42 foot gap and over the rest of the spillway would be 16,130 cfs.

The 6000 cfs peak outflow which would result from dam failure for the first set of conditions would be contained within the main stream channel and would probably have few, if any, adverse consequences downstream.

In the second case, a streamflow of 14,960 cfs is assumed prior to the dam failure. This assumption would result in a flooding condition of some low-lying flood plain areas downstream of the dam. In particular, a developed area on the left bank of the river about one mile downstream of the dam would experience flooding with maximum depth of about 2 feet. The assumed dam failure would then increase the discharge by less than 10 percent to a peak of 16,130 cfs, and flood depths at the developed area would increase by an increment of less than one foot.

Further downstream, there are no structures endangered by these flood levels for about another 2 miles. Since the Mine Falls Dam is a run-of-the-river structure with little storage and as this 2-mile reach has a fairly extensive flood plain, the dam failure flood wave should be largely attenuated here and present little hazard further downstream.

Another aspect of dam failure at Mine Falls concerns the gate house to the right of the dam which serves to control inflow to the Nashua Canal and Mill Pond. The emergency canal outlets were provided to protect the canal banks from damage by overtopping and the mill yards downstream from damage by flooding. According to the previously referenced reports by Hamilton Engineering Associates and Smith and Hamilton, Inc., these outlets are of sufficient capacity to safely pass high inflows which result from high stages of the Nashua River through the one operating head gate. However, in the event of failure of one or more of the four remaining gates (and closure slab) at a high river stage, it is apparent that the capacity of the canal and emergency outlets would be exceeded with some damage at the canal banks and at the mill yard as a consequence. No analysis of the extent or severity of such flooding, or of the likelihood of failure of the head gates is presented here.

SECTION 6 - STRUCTURAL STABILITY

6.1 Evaluation of Structural Stability

(a) Visual Observations

The field investigation revealed no significant displacement or distress that would warrant the preparation of structural stability calculations, based on assumed sectional properties and engineering factors.

There has been some concrete deterioration at the left end wall and some seepage through joints. The sluice gates could not be observed because they were submerged, but there was visible evidence of flow through gate No. 5.

(b) Design and Construction Data

No plans or calculations of value to a stability assessment are available for this dam.

(c) Operating Records

The dam survived the flood of 1936 which had recorded water levels of 10.5 feet above the spillway crest. It is not clear that the dam is in the same condition as it was in 1936 however.

(d) Post Construction Changes

The installation of precast concrete bulkheads at the upstream entrances to gates 1, 3, and 5 has limited flow control to the canal to one gate. The other gate is not operable. The bulkheads were installed in 1971-1972.

(e) Seismic Stability

The dam is located in Seismic Zone No. 2 and, in accordance with recommended Phase 1 guidelines, does not warrant seismic analysis.

SECTION 7 - ASSESSMENT, RECOMMENDATIONS AND REMEDIAL MEASURES

7.1 Dam Assessment

(a) Condition

The Mine Falls Dam is in FAIR condition at the present time. The sluice gate stems are in very poor condition at the present time.

(b) Adequacy of Information

The lack of in-depth engineering data does not permit a definitive review. Therefore, the adequacy of the dam cannot be assessed from the standpoint of reviewing design and construction data. This assessment is based primarily on the visual inspection, past performance, and sound engineering judgment.

(c) Urgency

The engineering studies and recommendations regarding the condition of the sluice gates should be implemented by the owner within one year of receipt of the Phase 1 inspection report.

(d) Need for Further Investigation

Additional investigations should be performed by the owner as outlined in paragraph 7.2.

7.2 Recommendations

It is recommended that a registered professional engineer be engaged by the owner to do the following.

- (1) Perform an engineering investigation of the physical condition of the 5 sluice gates.
- (2) Perform an engineering investigation to determine the extent of masonry unravelling of the downstream headwall.
- (3) Perform an engineering investigation to determine the source of seepage through the outcrop immediately downstream of the right end of the abutment.
- (4) Perform an engineering investigation to evaluate the effect of a failure of one or more of the canal gates on flooding in the canal and downstream areas.

The findings of these studies should be implemented by the owner.

7.3 Remedial Measures

The following remedial measures should be taken at the dam.

- (1) Reconstruct the left canal wall on a competent foundation.
- (2) Repair cracks in the left end wall of the dam.
- (3) Perform a technical inspection of the dam every year.

7.4 Alternatives

There are no meaningful alternatives to the recommendations outlined above.

APPENDIX A
VISUAL INSPECTION CHECKLIST

INSPECTION TEAM ORGANIZATION

Date: November 8, 1978

NH 00116
MINE FALLS DAM
Nashua, New Hampshire
Nashua River
NHWRB 165.01

Weather: Clear, 50°F ±

INSPECTION TEAM

Nicholas Campagna	Goldberg, Zoino, Dunnicliff & Associates, Inc. (GZD)	Team Captain
Robert Minutoli	GZD	Geotechnical
Andrew Christo	Andrew Christo Engineers (ACE)	Structural
Paul Razgha	ACE	Concrete
Guillermo Vicens	Resource Analysis, Inc.	Hydrology

The inspection team was accompanied by the following:

Ed Schroeder, Superintendent of Nashua Parks & Recreation Dept.
Another representative of Nashua Parks & Recreation Dept.
Pattu Kesavan, New Hampshire Water Resources Board.

CHECK LISTS FOR VISUAL INSPECTION

AREA EVALUATED	BY	CONDITION & REMARKS
DAM SUPERSTRUCTURE		
A. General		
Vertical alignment and movement	AC	No deficiencies noted
Horizontal alignment and movement		No deficiencies noted
B. Left End Wall		
Condition of concrete		Poor
Spalling		Adjacent to horizontal cracks
Erosion		Upstream end badly eroded
Cracking		A series of horizontal cracks on front face 20' ± long. Continuous 2" wide horizontal crack on upstream face
Rusting or staining of concrete		None noted
Visible reinforcing		Reinforcing exposed on a portion of upstream face
Efflorescence		In excess of 80% over front face below original elevation of top of wall
Seepage		None noted
C. Right Spillway Abutment		
Condition of concrete cap	AC	Fair, downstream vertical face honeycombed over 10% of its vertical face

CHECK LISTS FOR VISUAL INSPECTION

AREA EVALUATED	BY	CONDITION & REMARKS
<p>C. Right Spillway Abutment (cont.)</p> <p>Condition of stone masonry</p> <p>Seepage</p>	AC	<p>No deficiencies noted with the exception of eroded mortared joints</p> <p>Minor through open joints. Seepage at the rate of 10 to 15 gpm through rock fissures adjacent to the abutment. Steady flow through 8" dia. pipe at the rate of 3 to 5 cfs</p>
<p>D. Right Spillway "J" Training Wall</p> <p>Condition of stone masonry</p> <p>Seepage</p>		<p>No deficiencies noted with the exception of minor joint erosion at the spillway crest elevation. Joint efflorescence is minor</p> <p>None noted</p>
<p>E. Right Upstream Training Wall</p>		<p>No deficiencies noted with the exception of minor joint erosion at the spillway crest elevation. Joint efflorescence is minor</p>
<p>F. Cut-off wall</p>		<p>Top surface exposed, balance is completely buried</p>
<p>G. Head Wall</p> <p>Condition of masonry</p>	AC	<p>Lower left corner unravelled at channel water surface 2' high, 12" wide and 2' to 3' deep. Portions of parapet wall capstones missing</p>

CHECK LISTS FOR VISUAL INSPECTION		
AREA EVALUATED	BY	CONDITION & REMARKS
G. Head Wall (cont)	AC	
Seepage		None noted
Efflorescence		High degree of joint efflorescence and minor exudation on section of head wall immediately downstream of headworks between canal water surface and granite sill, 13' \pm high
Outlet tunnel headers		Mortared joints eroded
Chain link fence		Fair condition
Iron rail fence	AC	Abandoned
H. Canal Training Wall		
Condition of masonry		No deficiencies noted
Foundation		Fissures in bedrock eroded up to 2' under wall
Vegetation	AC	Trees and saplings up to 6" diameter growing in rock fissures
I. Intermediate Wall		With the exception of dislodged capstones this wall is in fair condition
OUTLET WORKS		
A. Spillway	PR	
Condition of stone masonry		No deficiencies noted with the exception of eroded mortared joints
Seepage	PR	Isolated over entire length of structure

CHECK LISTS FOR VISUAL INSPECTION

AREA EVALUATED	BY	CONDITION & REMARKS
B. Waste Outlet Flume	PR	
Condition of stone masonry		No deficiencies noted
Seepage		None noted
C. Headworks Structure	PR	
Condition		No deficiencies noted with the exception of the left side entrance being sealed off by means of welding
Gate operating equipment		Motorized operating drive non-functional, partially dismantled and power no longer available. Manual operation extremely difficult
Sluice gate openings		Openings to gates 1,3 and 5 have been sealed with pre-cast concrete panels
Sluice gates		
Condition of gates		Gates submerged and could not be observed
Gate #1		Gate frames in good condition
Gate #2		Rack gears greased but not operable
Gate #3		Gate frames completely rotted
Gate #4		Operable and raised 4". Frame heavily braced with cross framing and horizontal members. Base of stems badly rotted

CHECK LISTS FOR VISUAL INSPECTION

AREA EVALUATED	BY	CONDITION & REMARKS
Gate #5	PR	Gate frames disintegrated. Audible evidence of flow. Parks Dept. indicated it is open 6" and cannot be closed
Stop logs		No provisions for stop logs
Trash racks	PR	No provisions for trash racks
RESERVOIR		
A. Shoreline		
Evidence of slides	NAC	None noted
Potential for slides		Shoreline stable
B. Sedimentation		None noted
C. Upstream Hazard Areas in Event of Backflooding		None noted
D. Changes in Nature of Watershed (agriculture, logging, construction, etc.)		None noted
DOWNSTREAM CHANNEL		
A. Loose Rock or Trees Overhanging Channel		None noted
B. Condition of Channel		Rocky bottom with steeply sloping sides
OPERATION AND MAINTENANCE FEATURES		
A. Reservoir Regulation Plan		
Normal procedures		No formal plan
Emergency procedures	NAC	No formal plan

CHECK LISTS FOR VISUAL INSPECTION		
AREA EVALUATED	BY	CONDITION & REMARKS
Reservoir Regulation Plan- (cont)		
Compliance with designated plan	NAC	Need a more formal plan
B. Maintenance		
Quality		Some maintenance repairs needed
Adequacy	NAC	Situation indicates a more rigorous program needed

APPENDIX B

		<u>Page</u>
FIGURE 1	Site Plan	B-2
	Plan of Dam	B-3
	Details of Gate House (October 1971)	B-4
	List of pertinent records not included and their location	B-5

DOWNSTREAM
ISLANDS

NASHUA RIVER

GATEHOUSE

CANAL TO MILL POND

USGS ELEV. 155

NOTE: PHOTOS No. 2 & 3 OF THE
EMERGENCY SPILLWAY
STRUCTURES DO NOT APPEAR
ON THIS LOCATION PLAN.

GOLDBERG, ZOINO, DUNNICLIFF & ASSOC., INC.
GEOTECHNICAL CONSULTANTS
NEWTON UPPER FALLS, MASS.

U.S. ARMY ENGINEER DIV. NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

NATIONAL PROGRAM OF INSPECTION OF NON-FED. DAMS

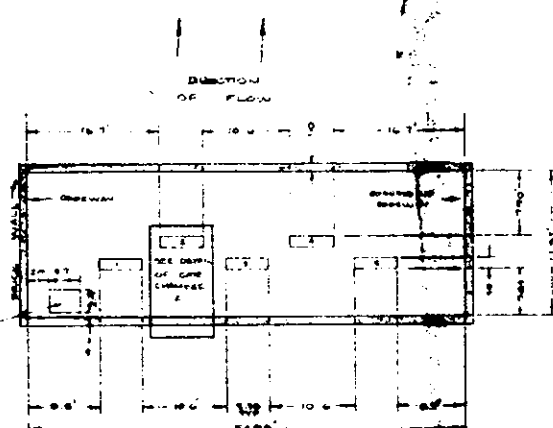
SITE PLAN

FILE No. 2201

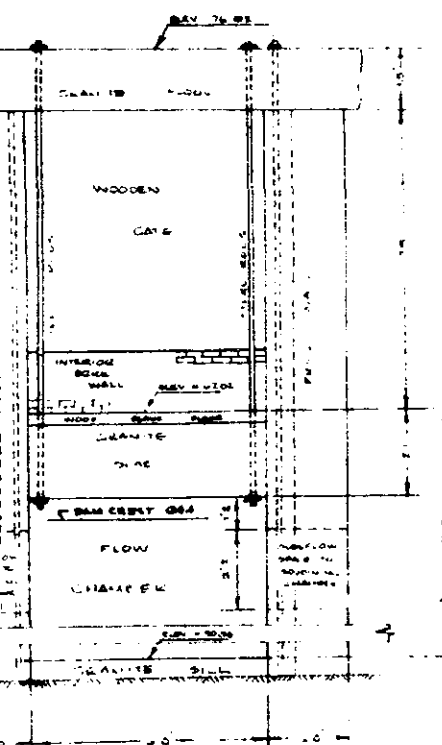
MINE FALLS DAM

NEW HAMPSHIRE

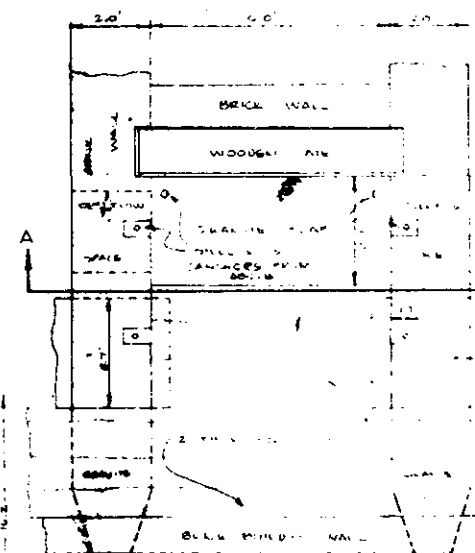
SCALE 1" = 200'
DATE NOVEMBER 1978



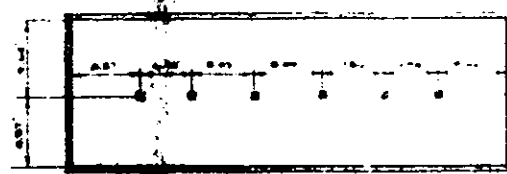
PLAN VIEW SHOWING
GATE SLOTS IN TOP FLOOR
SCALE 1" = 10'



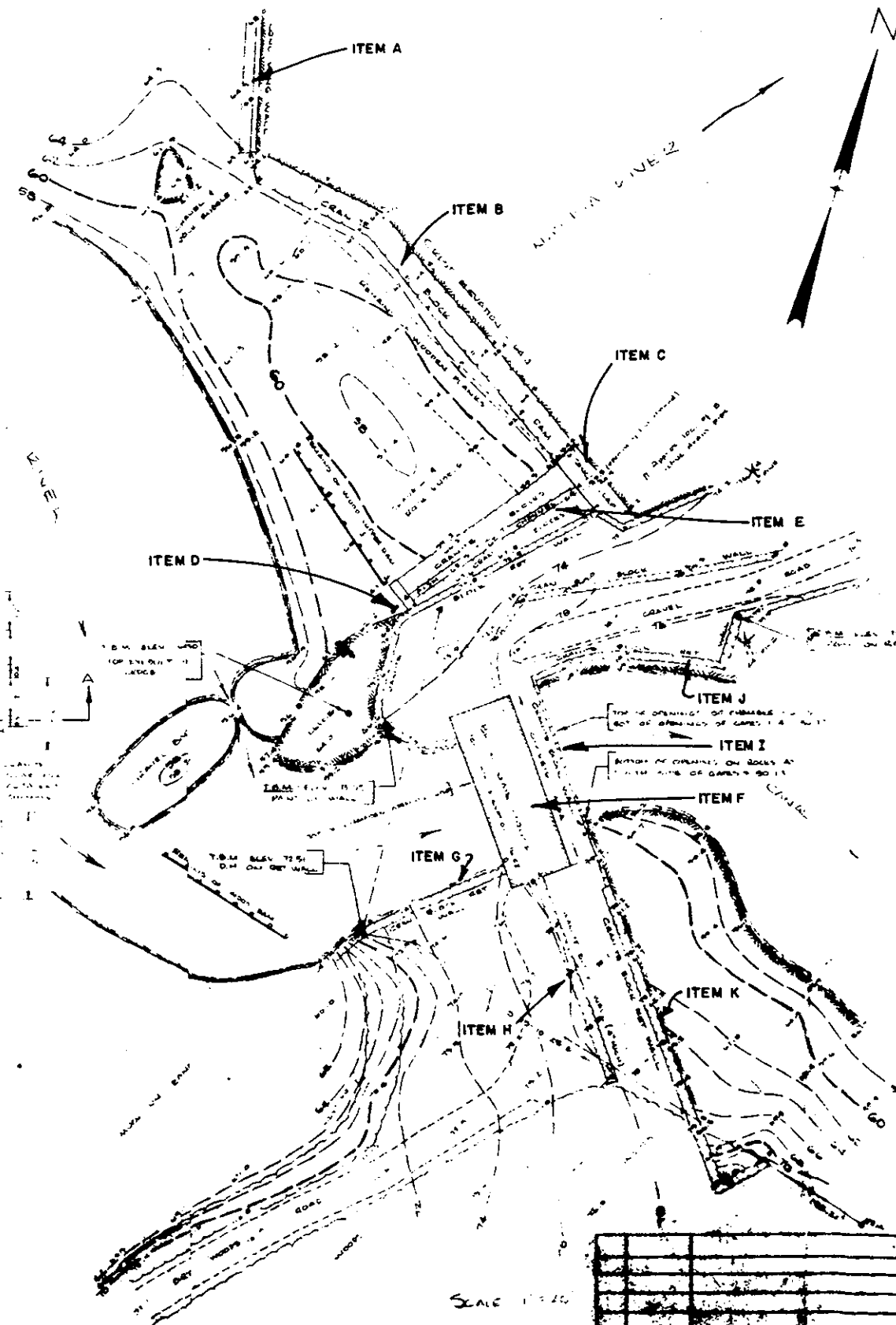
SECTION A-A
GATE STRUCTURE
SCALE 1" = 10'



DETAIL OF GATE STRUCTURE
SCALE 1" = 10'



SECTION OF 10'-0" WIDE
POINTS ON TOP FLOOR
SCALE 1" = 10'



NOTE: DRAWING HAS BEEN REDUCED
SCALES ARE NOT AS SHOWN

PLAN REFERENCE:
1. BUREAU OF LAND REVENUE TO KATHIAWAR NEW WATERWORKS
FOUNDATION, SCALE 1" = 100', DEC. 25, 1970, BY KATHIAWAR
ENGINEERING ASSOCIATES, INC., RAIPUR, INDIA.

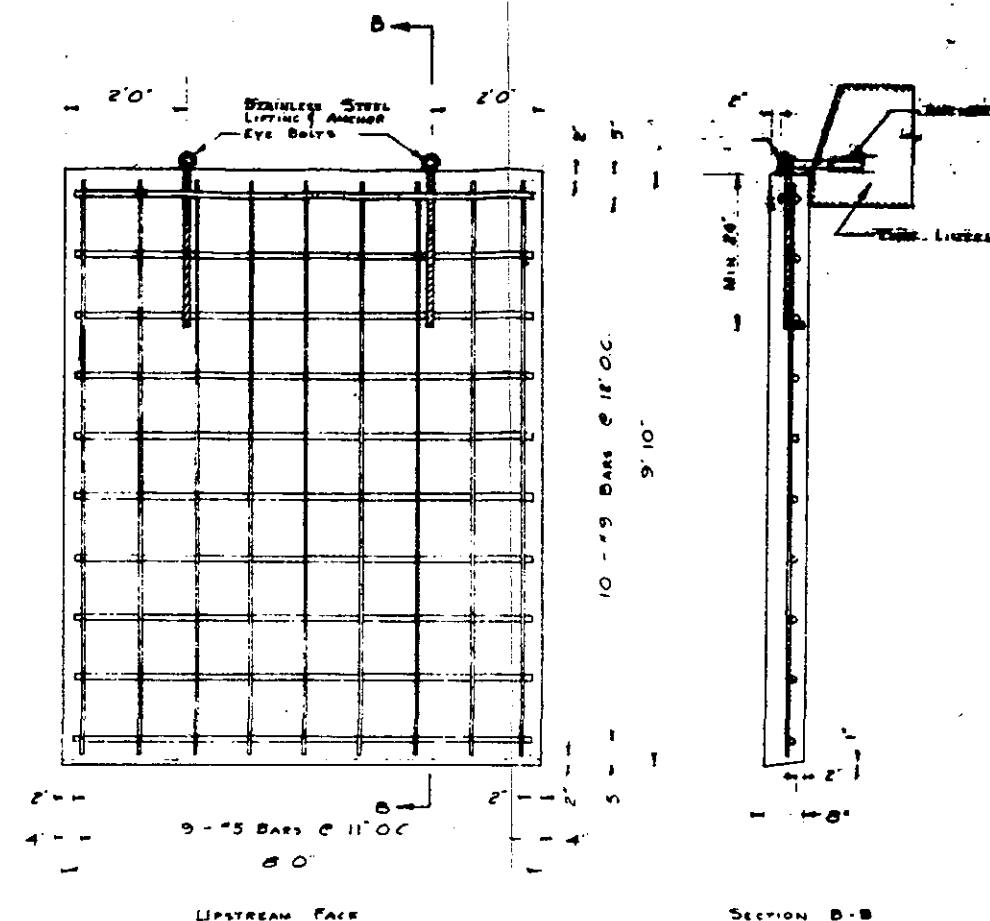
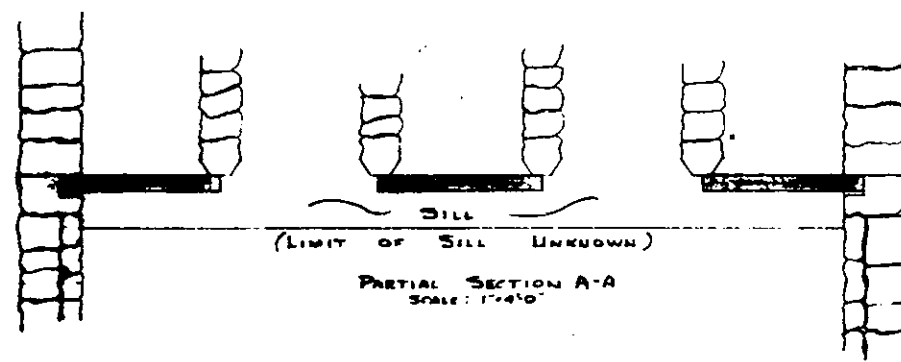
RECEIVED
DEC 20 1971
NEW DELHI
WATER RESOURCES BOARD

SITE PLAN MINE FALLS GATE HOUSE PROJECT

DESIGNED BY	SCALE AS SHOWN	SITE AREA
DRAWN BY		
CHECKED BY		
APPROVED BY		



HEADWORKS STRUCTURE



GATE CLOSURE SLAB
SCALE: 3/4"=1'-0"

NOTE: DRAWING HAS BEEN REDUCED
SCALES ARE NOT AS SHOWN

1. GATE CLOSURE SLABS ARE MADE OF AIR ENTRAINED CONCRETE HAVING A MINIMUM 7 DAY STRENGTH OF 4,000 P.S.I.
2. REINFORCING STEEL TO A.S.T.M. SPECIFICATION A615 GRADE 60.
3. EACH EYE BOLT SHALL BE CAPABLE OF CARRYING THE TOTAL WEIGHT OF ONE SLAB.
4. EXISTING SILLS SHALL BE CLEANED OF ALL SILT AND DEBRIS BEFORE INSTALLING CLOSURE SLABS.
5. EYE BOLTS, ANCHORS AND BOLTS SHALL BE STAINLESS STEEL INCLUDING WASHERS AT HEAD OF BOLTS.
6. THE BOTTOM OF THE SLAB SHALL HAVE A SLOPE OF 1" IN 8'.
7. TOP AND SIDES OF UPSTREAM FACE SHALL HAVE A 1" CHAMFER.

A. THE SLABS WERE INSTALLED ON OCT 15, 1971.

AS BUILT

NASHUA NEW HAMPSHIRE FOUNDATION
MINE FALLS GATE HOUSE PROJECT
GATE HOUSE ELEVATION
AND
GATE CLOSURE SLAB DETAIL

SCALE AS NOTED

DATE: SEPTEMBER 25, 1971

DESIGNED BY: N.T.D.
DRAWN BY: N.T.D.
CHECKED BY: L.P.S.
APPROVED BY: N.H.F.

SHOWN ENGINEERING ASSOCIATES, INC.
NASHUA, NEW HAMPSHIRE
SHEET 2 OF 2 749

B-4

1-71-57-749

The New Hampshire Water Resources Board (NHWRB), located at 37 Pleasant Street, Concord, New Hampshire 03301, maintains a comprehensive correspondence file for this dam. Included in this file are the following items:

- (1) A February 1928 letter from Chas. T. Main, Inc. regarding the repairs to Mine Falls Dam.
- (2) A record of gage readings at the dam for various dates from January to April 1936.
- (3) A record of water used by the mill in early 1936.
- (4) A NHWRB "Inventory of Dams and Water Power Development" dated August 1936.
- (5) A Public Service Commission of New Hampshire "Dam Record" dated August 31, 1936.
- (6) A NHWCC "Data on Dams in New Hampshire" dated April 10, 1939.
- (7) A June 1940 and a June 1951 New Hampshire Water Control Commission (NHWCC) "Report on Dam Inspection."
- (8) A June 29, 1951 letter from NHWRB to Textron, Inc. describing required repairs to the dam.
- (9) A December 1971 report by Hamilton Engineering, Inc. entitled "Hydraulics and Control Facilities of the Nashua River Canal."

APPENDIX C
SELECTED PHOTOGRAPHS

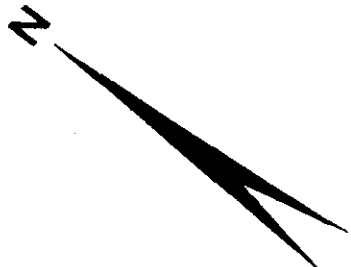
DOWNSTREAM
ISLANDS

NASHUA RIVER

GATE HOUSE

CANAL TO MILL POND

USGS ELEV. 155



OVERVIEW



APPENDIX C

FILE No. 2201

GOLDBERG, ZIMNO, DUNNCLIFF & ASSOC., INC.
GEOTECHNICAL CONSULTANTS
NEWTON UPPER FALLS, MASS.

U.S. ARMY ENGINEER DIV. NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

NATIONAL PROGRAM OF INSPECTION OF NON-FED. DAMS

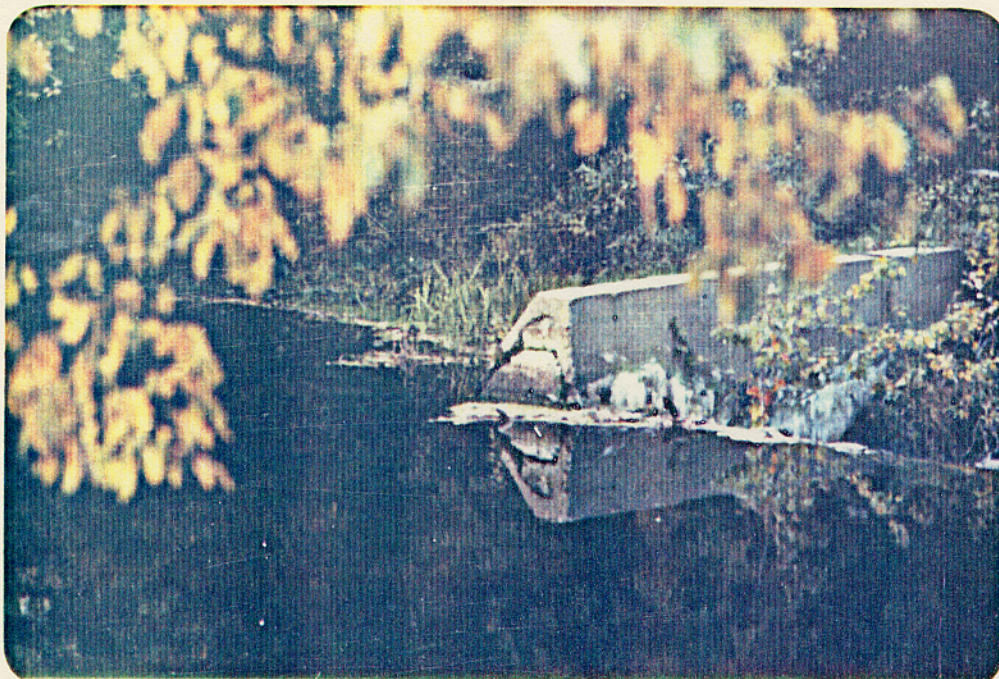
LOCATION AND ORIENTATION OF PHOTOS

MINE FALLS DAM

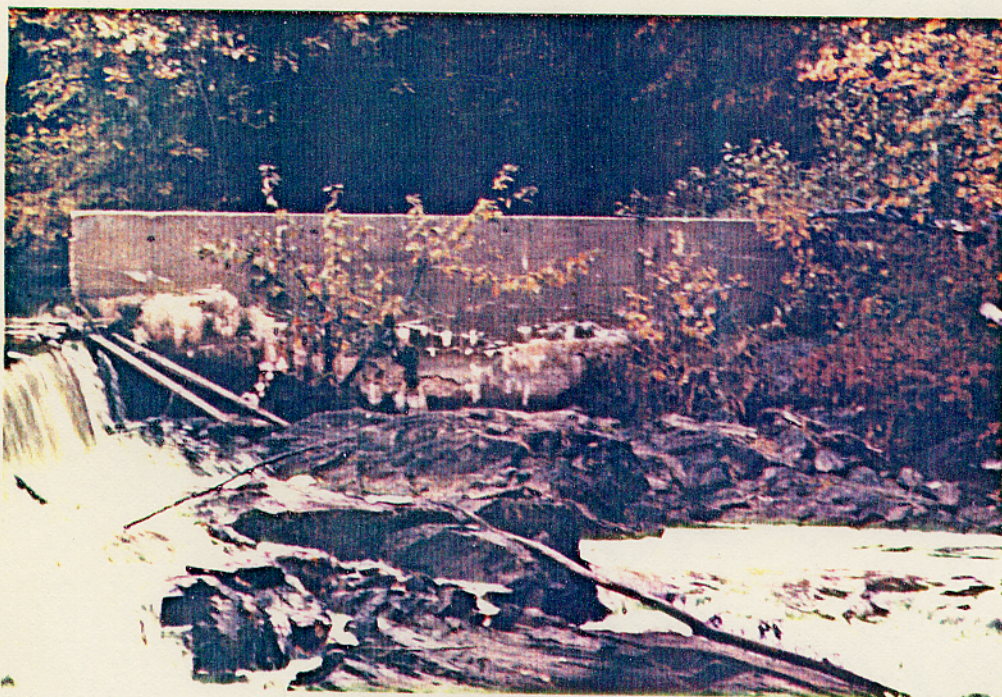
NEW HAMPSHIRE

SCALE 1" ≈ 200'

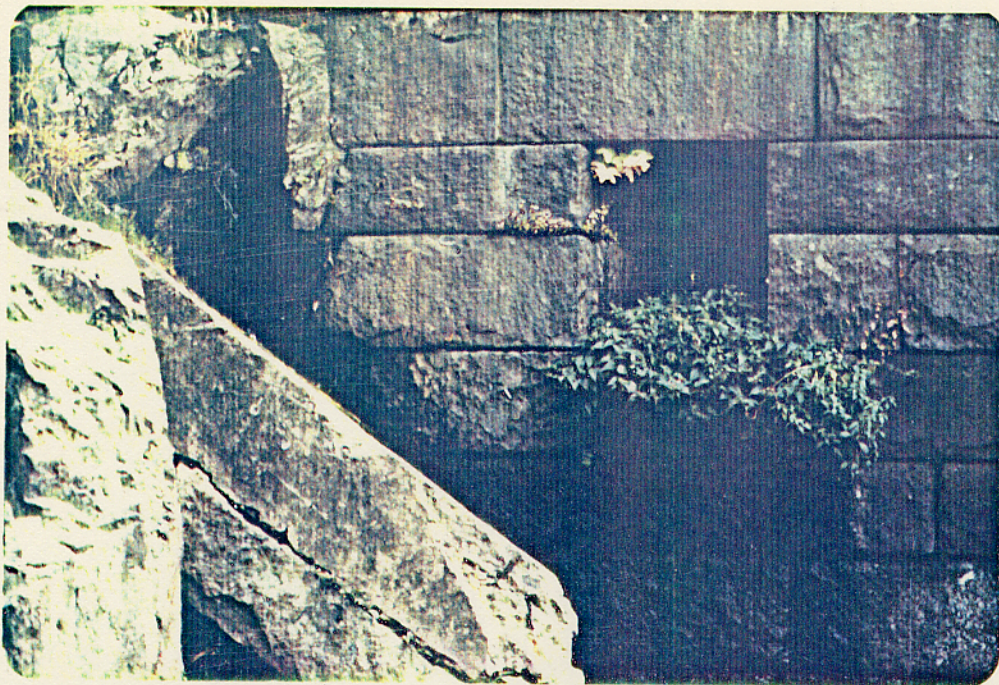
DATE NOVEMBER 1978



1. View of left end wall showing concrete cap over old ogee section and deterioration of concrete



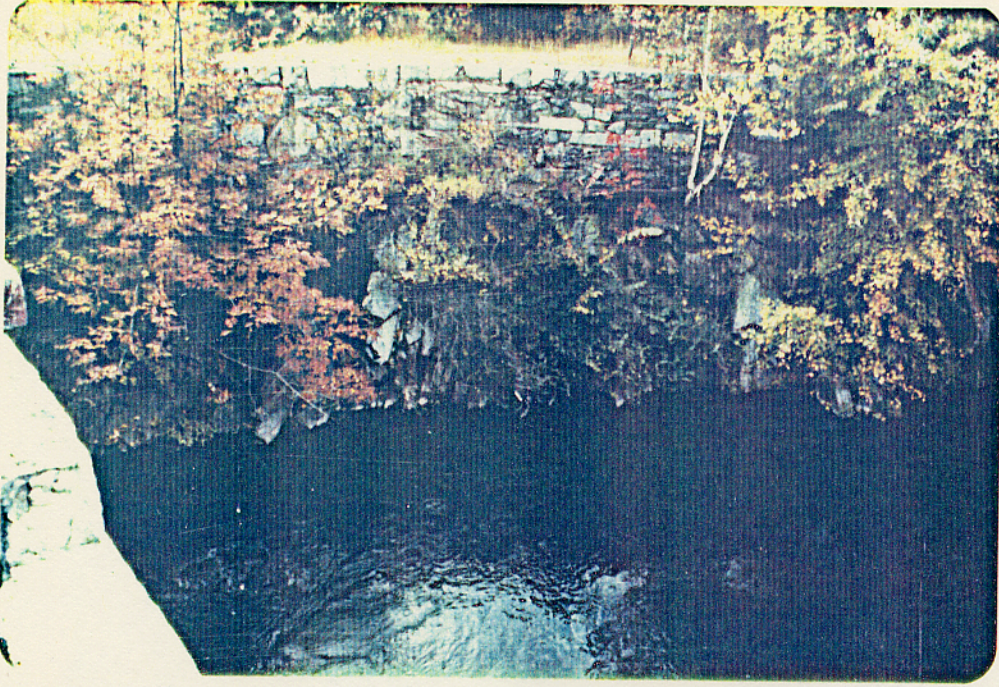
2. View of left endwall from downstream side



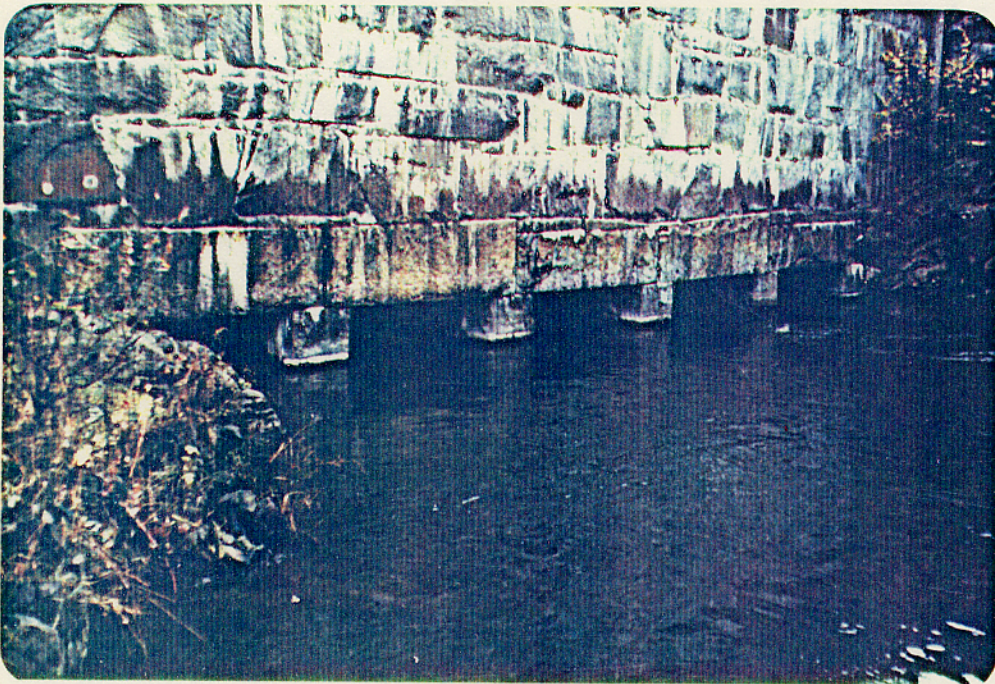
3. View from downstream of seepage at right spillway abutment and old flume



4. Detail view of seepage in photo 3 above



5. View of highly jointed rock under downstream canal training wall at left side of canal just downstream of headworks structure



6. View of outlets for timber sluice gates of the headworks structure

APPENDIX D
HYDROLOGIC/HYDRAULIC
COMPUTATIONS

I Dam Rating Curve

See page 2 for schematic sketch of over-flow (and underflow) section based on FIS X-section data and on a site plan prepared in 1971 by Hamilton Engineering Assoc. Following present operating policy, it is assumed that 1 canal headgate is always completely open. (3 of 5 are sealed w/ concrete slabs)

Datum -- spillway crest, elev 151.8

Head gate underflow

$$Q = C_h \times B \times D \sqrt{2g((H+13.7) - C_h \times D)}$$

C_h = discharge coefficient

B = gate width

D = " height

$H+13.7$ = head on gate sill

(Henderson
Open Channel
Flow, p. 2)

$$Q_1 = .7 \times 6.0 \times 9.5 \sqrt{2 \times 32.2 \times (H+13.7 - .7 \times 9.5)}$$

Weir overflow

(weir overflow)

$$Q = CL \times H^{3/2}$$

C = weir coefficient

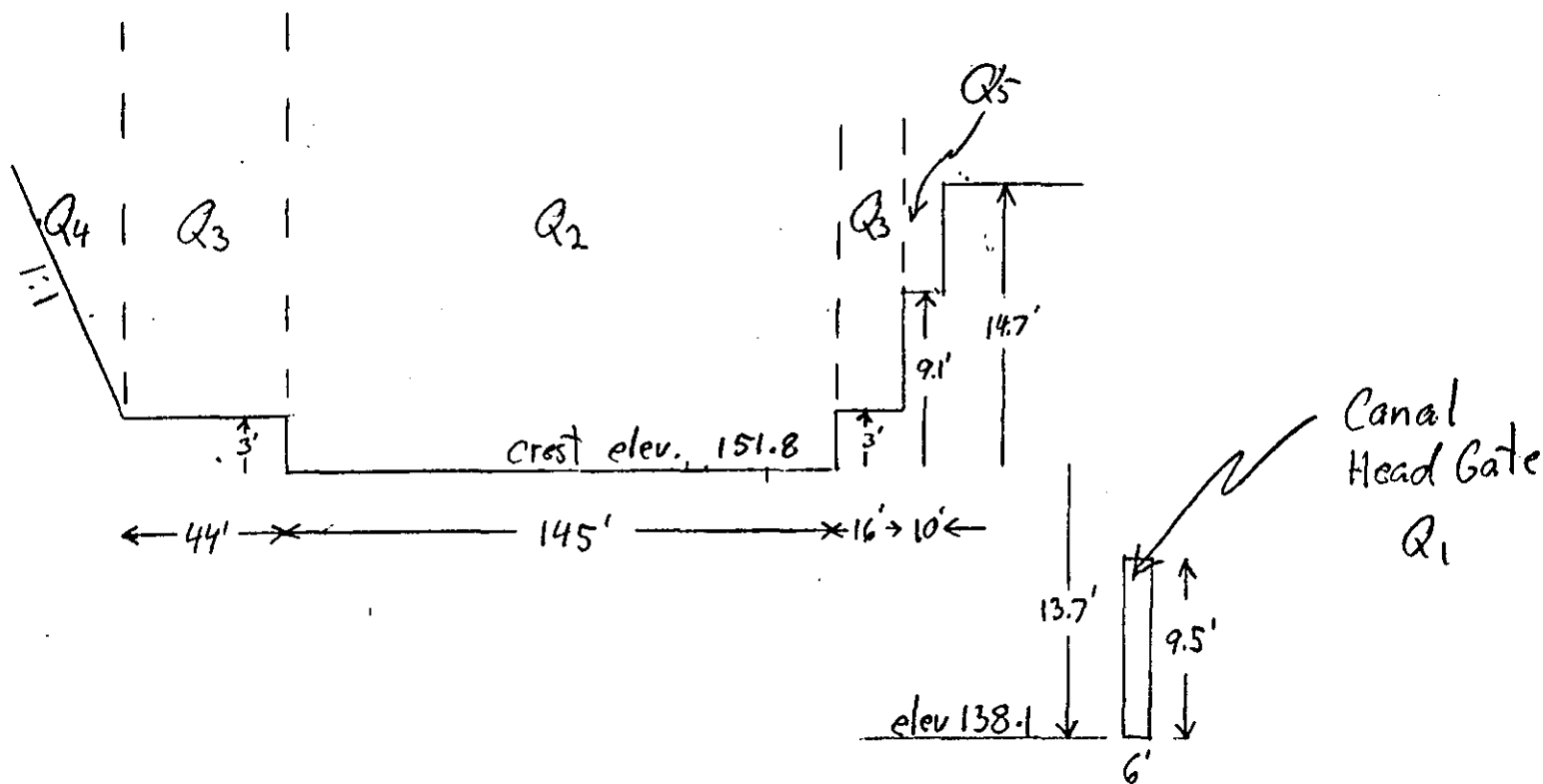
L = crest length

H = head on crest

$$Q_2 = 3.1 \times 145 \times H^{1.5}$$

$$Q_3 = 3.1 \times (44+16) \times (H-3.0)^{1.5}$$

Schematic Overflow Section Mine Falls Dam



Site # 165 Dam Safety Mine Falls Dam 11/17 2/23/22 2/14

165 Dam Safety Mine Falls Dam VCH 2/23/79 3/24

$$Q_4 = 2.8 \times (H - 3.0) \times (.5 \times (H - 3.0))^{1.5}$$

$$Q_5 = 2.8 \times 10 \times (H - 9.1)^{1.5}$$

A BASIC program was written to calculate an aggregate stage-discharge function at the dam. A listing is shown on page 4, followed by tabulated output and a plotted curve.

list

```
90 REM: STORED ON TAPE 18, FILE 51
100 REMARK: STAGE-DISCHARGE FOR MINE FALLS DAM
110 REMARK: ONE CANAL HEADGATE OPEN
120 PAGE
130 PRINT "DISCHARGE FROM MINE FALLS DAM W/ ONE CANAL HEADGATE OPEN"
140 PRINT USING 150:
150 IMAGE /2T"HEAD"30T"DISCHARGE"
160 PRINT USING 170:
170 IMAGE 1T"(FEET)"32T"(CFS)"
180 PRINT USING 190:
190 IMAGE 10T"TOTAL GATE SPILLWAY DAM CREST SIDE SLOPES"
200 FOR H=0 TO 14.5 STEP 0.5
210 Q1=0.7*6*9.5*(2*32.2*(H+13.7-0.7*9.5))1.5
220 Q2=3.1*145*H1.5
230 Q3=0
240 Q4=0
250 Q5=0
260 IF H<=3 THEN 320
270 Q3=3.1*(44+16)*(H-3)1.5
280 Q4=2.8*(H-3)*(0.5*(H-3))1.5
300 IF H<=9.1 THEN 320
310 Q5=2.8*10*(H-9.1)1.5
320 Q6=Q4+Q5
330 Q7=Q1+Q2+Q3+Q6
340 PRINT USING 350:H,Q7,Q1,Q2,Q3,Q6
350 IMAGE 2T,2D,2D,9D,8D,10D,11D,13D
360 NEXT H
370 END
```

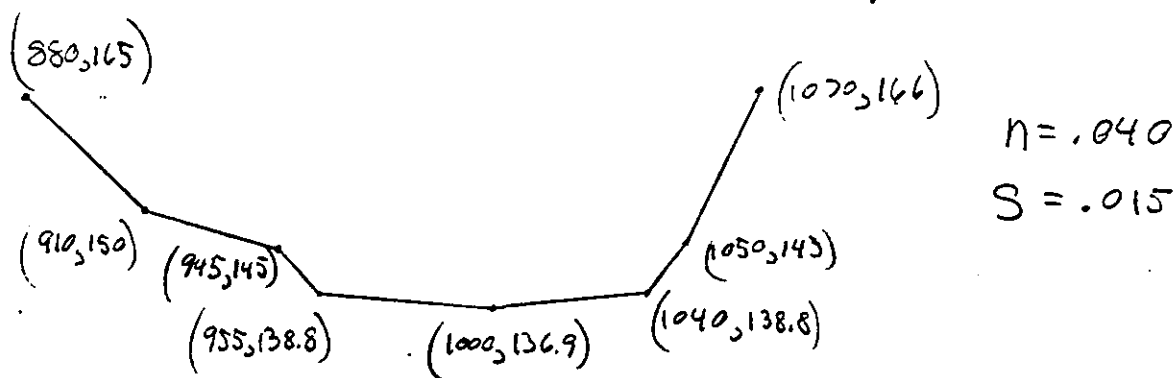
DISCHARGE FROM MINE FALLS DAM W/ ONE CANAL HEADGATE OPEN

HEAD (FEET)	DISCHARGE (CFS)				
	TOTAL	GATE (Q ₁)	SPILLWAY (Q ₂)	DAM CREST (Q ₃)	SIDE SLOPES (Q ₄ + Q ₅)
0.00	850	850	0	0	0
0.50	1039	880	159	0	0
1.00	1358	908	450	0	0
1.50	1762	936	826	0	0
2.00	2235	963	1271	0	0
2.50	2766	990	1777	0	0
3.00	3351	1015	2336	0	0
3.50	4049	1040	2943	66	0
4.00	4847	1064	3596	186	1
4.50	5724	1088	4291	342	3
5.00	6669	1111	5026	526	6
5.50	7677	1134	5798	735	10
6.00	8745	1157	6606	966	15
6.50	9868	1179	7449	1218	23
7.00	11045	1200	8325	1488	32
7.50	12272	1221	9233	1776	43
8.00	13548	1242	10171	2080	55
8.50	14871	1263	11139	2399	70
9.00	16240	1283	12137	2734	87
9.50	17660	1303	13162	3082	114
10.00	19134	1322	14214	3445	152
10.50	20654	1341	15294	3820	199
11.00	22221	1360	16399	4209	253
11.50	23831	1379	17530	4609	313
12.00	25484	1398	18685	5022	379
12.50	27178	1416	19865	5446	451
13.00	28913	1434	21069	5882	529
13.50	30688	1452	22296	6328	612
14.00	32502	1469	23546	6786	701
14.50	34354	1486	24819	7254	795

Tailwater Rating

FIS backwater computations indicate submergence of spillway overflow at high discharges. In order to check the effect of submergence on spillway discharge, and to more accurately estimate the consequences of dam failure given significant tailwater levels, a tailwater rating curve at the spillway is approximated.

Approx. X-section just d/s of dam



A simple BASIC program was used to calculate normal flow rate as a function of stage assuming the channel properties as shown. Page 2 is a normal flow rating table

DEPTH	ELEV	AREA	WPER	HYD-R	AR2/3	Q
0.0	136.9	0.0	0.0	0.0	0.0	0.0
2.0	138.9	89.3	85.5	1.0	91.9	419.2
4.0	140.9	266.4	93.1	2.9	537.2	2450.7
6.0	142.9	456.4	100.6	4.5	1250.8	5706.6
8.0	144.9	659.3	108.2	6.1	2200.1	10037.3
10.0	146.9	883.6	124.7	7.1	3262.3	14883.2
12.0	148.9	1139.7	141.6	8.1	4581.1	20899.7
14.0	150.9	1425.6	154.1	9.2	6286.5	28680.0
16.0	152.9	1726.4	161.4	10.7	8388.7	38270.7
18.0	154.9	2038.9	168.6	12.1	10751.2	49049.1
20.0	156.9	2363.3	175.8	13.4	13371.2	61001.5
22.0	158.9	2699.5	183.1	14.7	16247.1	74122.1
24.0	160.9	3047.4	190.3	16.0	19379.0	88410.3
26.0	162.9	3407.2	197.5	17.2	22767.6	103869.7
28.0	164.9	3778.8	204.8	18.5	26414.3	120506.9

D-8

Normal Flow

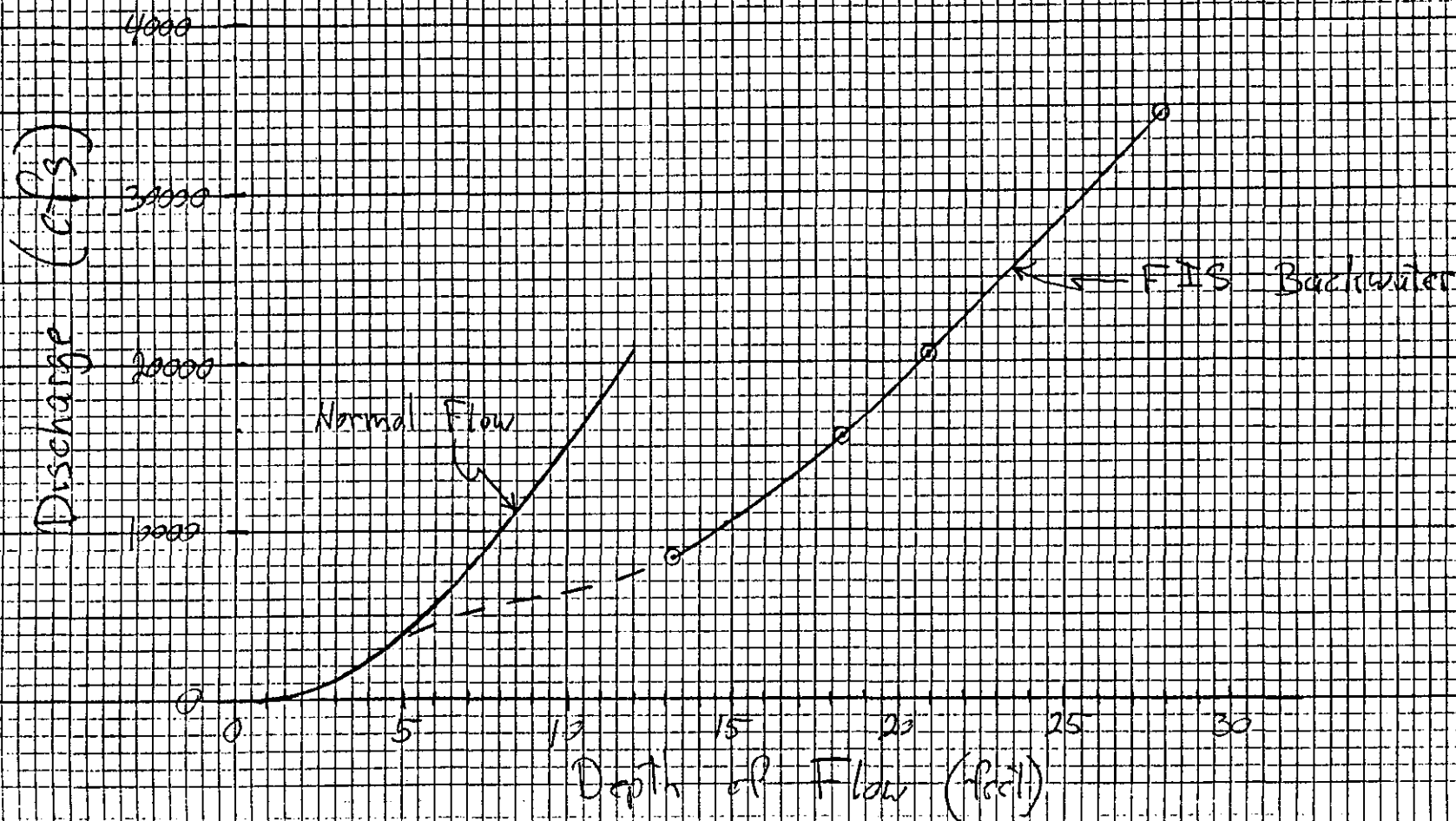
Nashua River

Station 5.288

The tailwater depths from FIS backwater computations (HEC-2) are considerably higher than those indicated by normal flow calculations. This is evidently the result of flow constriction at a very narrow section of channel about 200' d/s. As a detailed backwater analysis is not justified here, the tailwater rating curve is approximated by connecting those points available from FIS computations, then eyeballing a smooth transition to normal flow at low discharges. The curve is shown on page 9.

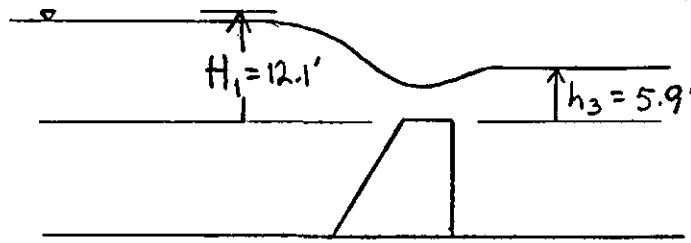
D-10

Mine Falls Dam Tailwater Rating Curve



hcl/c

Submergence effect on Spillway Discharge
Check 100 year flow

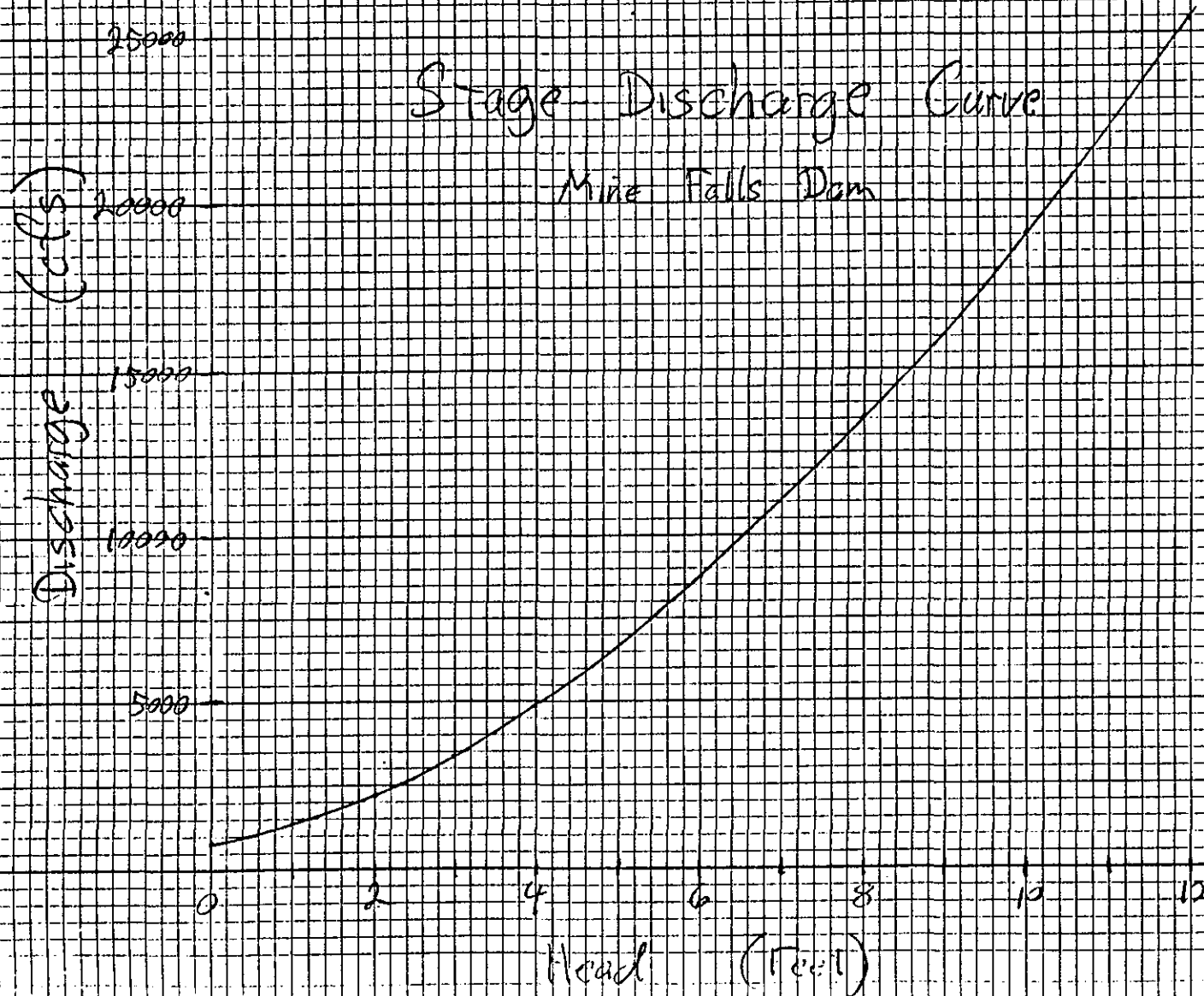


$$h_3/H_1 = \frac{5.9}{12.1} = .49$$

effect on discharge coefficient is
insignificant

based on Fig 4.03 "Effect of
weir geometry on submerged flow
discharge coefficients" in H.E.C.,
Water Surface Profiles

Use dam rating curve as calculated, neglecting
submergence



II Dam Failure Analysis

Dam failure will be considered under two different flow conditions because of some ambiguity in defining top of dam and to see the effect of high tailwater.

Breach Outflow

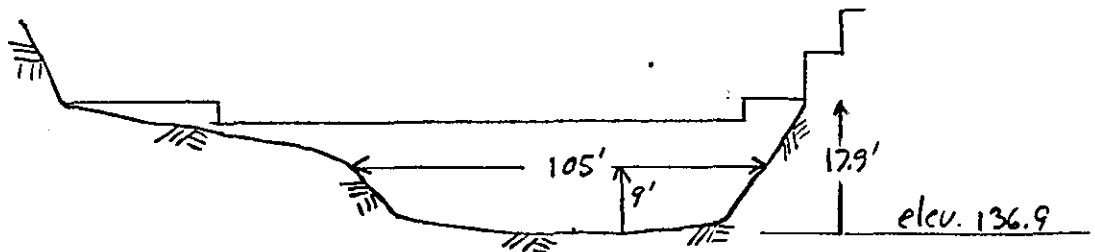
$$Q_{pi} = 8/27 \times W_b \times \sqrt{g} Y_o^{3/2}$$

W_b = breach width

$$\leq (\text{dam width at } 1/2 \text{ height}) \times 0.4$$

use

$$W_b = 105 \times 0.4 = 42' \quad \text{based on sketch below}$$



Simplified Section of Dam

Case 1

Assume dam fails when the walls flanking the main spillway are overlapped -- elev. 154.8

Normal Outflow

$$\begin{array}{rcl} H = 3.0' \Rightarrow Q_{tot} & = & 3350 \text{ cfs} \quad (\text{from dam rating curve}) \\ \text{subtract } Q_{gate} & - & 1010 \\ Q_{spillway} & = & 2340 \text{ cfs} \end{array}$$

Breach Outflow

$$Q_{pi} = \frac{8}{27} \times W_b \times \sqrt{g} \times Y_o^{3/2}$$

$$W_b = 42'$$

Y_o = depth of water from top of pool to tailwater

tailwater depth = 4' (from tailwater rating curve)
" elev. = 140.9

$$Y_o = 154.8 - 140.9 = 13.9'$$

$$Q_{pi} = \frac{8}{27} \times 42 \times \sqrt{g} \times 13.9^{3/2} = 3660 \text{ cfs}$$

Total Outflow in River Channel

$$Q = 2340 + 3660 = 6000 \text{ cfs}$$

Case 2

Assume dam fails when the water level exceeds the top of the stone retaining wall at the right abutment -- elev. 160.9

Normal Outflow

$$H = 9.1' \Rightarrow Q_{tot} = 16240 \text{ cfs}$$

$$\text{subtract } Q_{gate} \quad - 1280$$

$$Q_{dam} = 14960 \text{ cfs}$$

Breach Outflow

$$Q_{p1} = 8/27 \times W_b \times \sqrt{g} \times Y_o^{3/2}$$

$$W_b = 42$$

$$Y_o = 160.9 - 154.4 = 6.5'$$

$$\text{tailwater depth} = 17.5'$$

$$\text{" elev.} = 154.4$$

$$Q_{p1} = 8/27 \times 42 \times \sqrt{g} \times 6.5^{3/2} = 1170 \text{ cfs}$$

Total Outflow in River Channel

$$Q = 14960 + 1170 = 16130 \text{ cfs}$$

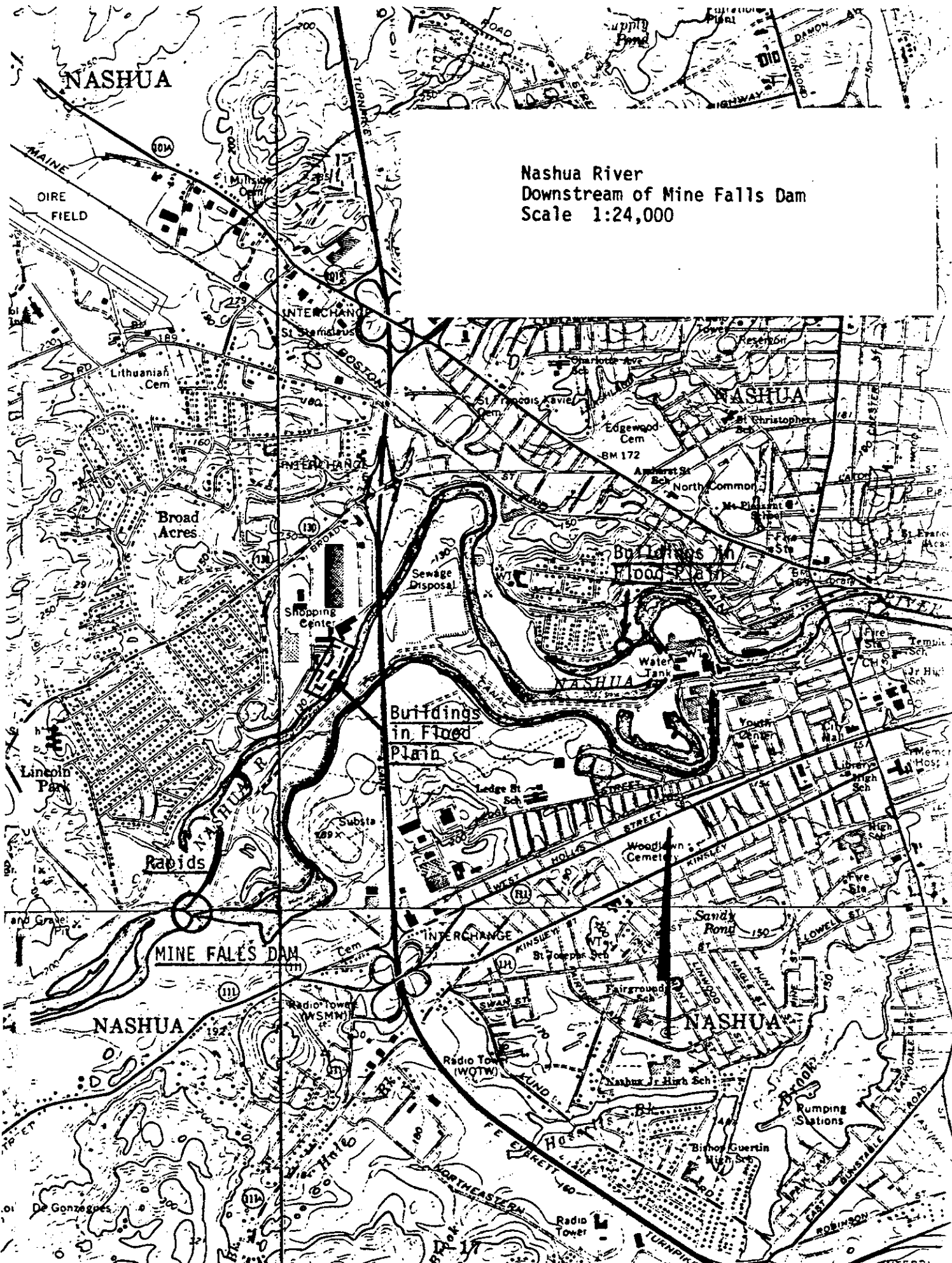
Downstream Flooding

Assessment of flooding d/s as a result of dam failure is based on Flood Boundary Work Maps for Nashua and on FIS back-water computations (HEC-2). A small scale map of the area is shown on the following page

Of particular interest are a group of buildings about 1 mile d/s at the left bank which lie within the 100 year floodplain boundary.

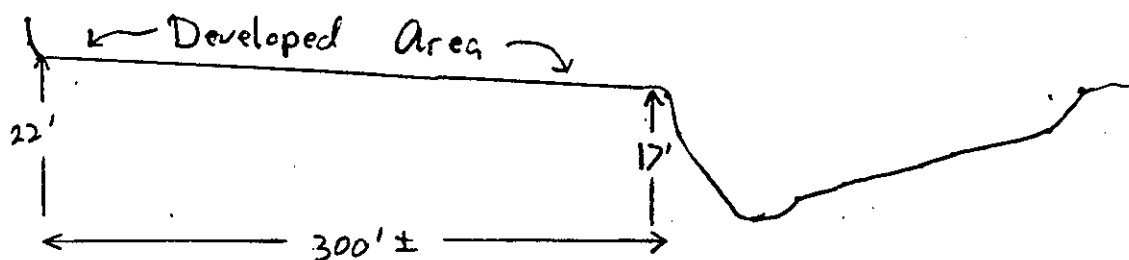
Note that the FIS 100 yr. flood of 20180 cfs > 16130 cfs which is the ^{larger} dam failure outflow under consideration. Hence, only areas within the 100-year boundary are of interest.

The next structures within the 100 year floodplain are some houses almost 3 miles d/s of the dam. However, as the Mine Falls dam is a run-of-the-river structure with little surcharge storage ^{behind it} and as the 2 mile reach u/s of the houses



Nashua River
Downstream of Mine Falls Dam
Scale 1:24,000

has a more extensive flood plain, the dam failure flood wave should be largely attenuated before reaching these houses. Incremental flood damage due to the dam break should be minimal.



Approx X-section 1 mile d/s

Approx. Stream Rating* 2 mile d/s

	Discharge	Depth of Flow
10yr.	8550	14.4'
50 yr.	15750	19.8'
100 yr.	20180	22.9'

* Estimated by averaging FIS computed depths at sections .2[±] mile ups and .2[±] mile d/s of development

Case 1

$$Q = 6000 \text{ cfs}$$

Depth $< 14.4'$ no flooding

Case 2

$$Q_{\text{normal}} = 14960 \text{ cfs}$$

\Rightarrow depth of flow $\approx 19.2'$

extent of flooding $\approx 120'$

depth of " $\approx 2.2'$ maximum

$$Q_{\text{tot}} = 16130 \text{ cfs} \quad (\text{normal flow plus dam break})$$

\Rightarrow depth of flow $\approx 20.1'$

extent of flooding $\approx 180'$

depth of " $\approx 3.1'$ max

Dam Failure Summary

- At medium stream flows (case 1) the dam failure ^{peak} will more than double the discharge but no flooding results d/s
- At high stream flows (case 2) the dam failure peak adds $< 10\%$ to the discharge. Flood depths at development 1 mile d/s (already inundated) will be increased $< 1'$ and flood extent increased $\sim 60'$.
- The valley above the dam is relatively narrow with steep banks, and as the dam is low this results in a small surcharge storage at the time of failure. The available storage in the floodplain, based on the average width and depth of flooding, should be sufficient to largely attenuate the peak dam break surge before it reaches the second group of structures 3 miles downstream, and thus the incremental flood damage at this point due to the dam break should be very limited.

III Test Flood Analysis

Size classification -- Small

- storage ≤ 1000 AF
- height $\leq 40'$

Hazard Classification -- Low

- Dam failure out-flow will not affect structures d/s unless stream stage is very high already (> 10 yr.). At such high stages, the dam failure will add less than 10% to the stream discharge.
- Storage behind this run-of-the-river dam is small, so the dam break flood wave will be quickly attenuated.
- No loss of life expected

Test Flood Selection

Per COE guidelines, a Small dam with Low hazard potential should use 50 year to 100 year test flood. Considering some possible incremental damage to a development downstream, choose 100 yr. flood

A 1977 FIS study by ANCO estimated 10, 50, 100, 500 year discharges at Mine Falls Dam as follows:

Recurrence Int.	Peak Discharge
10 yr.	8550 cfs
50 yr.	15750 cfs
100 yr.	20180 cfs
500 yr.	34500 cfs

Total Drainage area = 524 sq. mi (see map on page 22)
 yield from 117 sq. mi is diverted
 from the Wachusett Reservoir out of basin

Net Drainage area = 407 sq. mi

The 100 yr. discharge of 20180 cfs was computed at the dam, so that storage routing in the reservoir need not be considered. In any case, the surcharge storage available is too small to have much effect, especially considering the great runoff volumes from a watershed of this size. For this reason, a stage-storage relation has not been calculated for Mine Falls Dam.

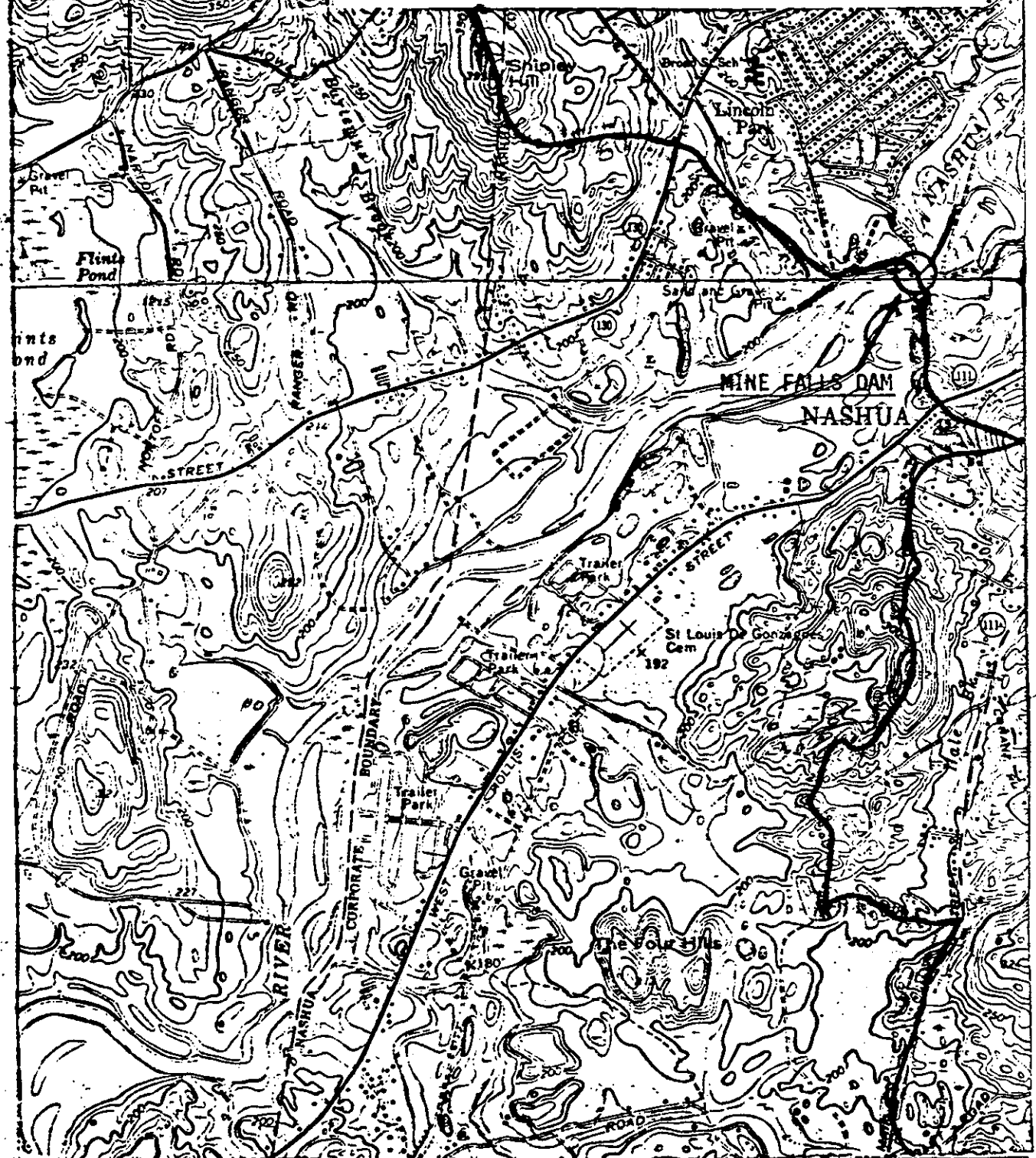
DRAINAGE AREA DELINEATION (PARTIAL)

MINE FALLS DAM

NASHUA, NEW HAMPSHIRE

DRAINAGE AREA = 524 SQUARE MILES

SCALE 1:62500



Largest Flood of Record

@ E. Peppercell gaging station

$$Q_{\text{peak}} = 20900 \quad (1936)$$

$$DA = 316 \text{ sq mi}$$

@ Mine Falls

$$DA = 407 \text{ sq mi}$$

estimate

$$Q_{\text{peak}} = \left(\frac{407}{316} \right)^{0.75} \times 20900 = 25270 \text{ cfs}$$

Test Flood Summary

Size -- Small

Hazard -- Low

Test Flood -- use 100 yr. peak

$$Q_{100} = 20180$$

$$\text{Head} = 10.3'$$

Defining top of dam as the top of the walls flanking the main spillway 3' above the crest, the Test Flood would be seen to overtop the dam by over 7'.

If top of dam is taken as the top of the stone retaining wall at the right abutment, then Test Flood levels are considered to be 1.2' above top of dam.

In either case, the spillway capacity is insufficient to pass the Test Flood.

APPENDIX E
INFORMATION AS CONTAINED IN
THE NATIONAL INVENTORY OF DAMS



INVENTORY OF DAMS IN THE UNITED STATES

STATE	IDENTITY NUMBER	DIVISION	STATE	COUNTY	CONGR. DIST.	STATE	COUNTY	CONGR. DIST.	NAME	LATITUDE (NORTH)	LONGITUDE (WEST)	REPORT DATE DAY MO YR
NH	116	NED	NH	011	02				NINE FALLS DAM	4244.9	7130.4	13MAR79

POPULAR NAME	NAME OF IMPONDMENT

REGION	BASIN	RIVER OR STREAM	NEAREST DOWNSTREAM CITY-TOWN-VILLAGE	DIST FROM DAM (MI.)	POPULATION
01	05	NASHUA RIVER	NASHUA	1	70000

TYPE OF DAM	YEAR COMPLETED	PURPOSES	STRUCTURAL HEIGHT (FT.)	HYDRAULIC HEIGHT (FT.)	IMPOUNDING CAPACITIES MAXIMUM (ACRE-FT.)	NORMAL (ACRE-FT.)	DIST	OWN	FED R	PRV/FED	SCS A	VER/DATE
PGGRCT	1928	0	24	24	650	500	NED	N	N	N	N	13MAR79

REMARKS
21-STONE MASONRY CONCRETE 22-REBUILT 23-NONE

D/S HAS	SPILLWAY CREST LENGTH	TYPE	WIDTH (FT.)	MAXIMUM DISCHARGE (FT.)	VOLUME OF DAM (CY)	POWER CAPACITY INSTALLED (MW)	PROPOSED (MW)	NO.	LENGTH (FT.)	WIDTH (FT.)	LENGTH (FT.)	WIDTH (FT.)	LENGTH (FT.)	WIDTH (FT.)	LENGTH (FT.)	WIDTH (FT.)
3	325	C	145	14900												

OWNER	ENGINEERING BY	CONSTRUCTION BY
CITY OF NASHUA		

REGULATORY AGENCY			
DESIGN	CONSTRUCTION	OPERATION	MAINTENANCE
NH WATER RES BD	NH WATER RES BD	NH WATER RES BD	NH WATER RES BD

INSPECTION BY	INSPECTION DATE DAY MO YR	AUTHORITY FOR INSPECTION
GOLDBERG ZUINO DUNNICLIFF ASSOC	08NOV78	PUBLIC LAW 92-367

REMARKS